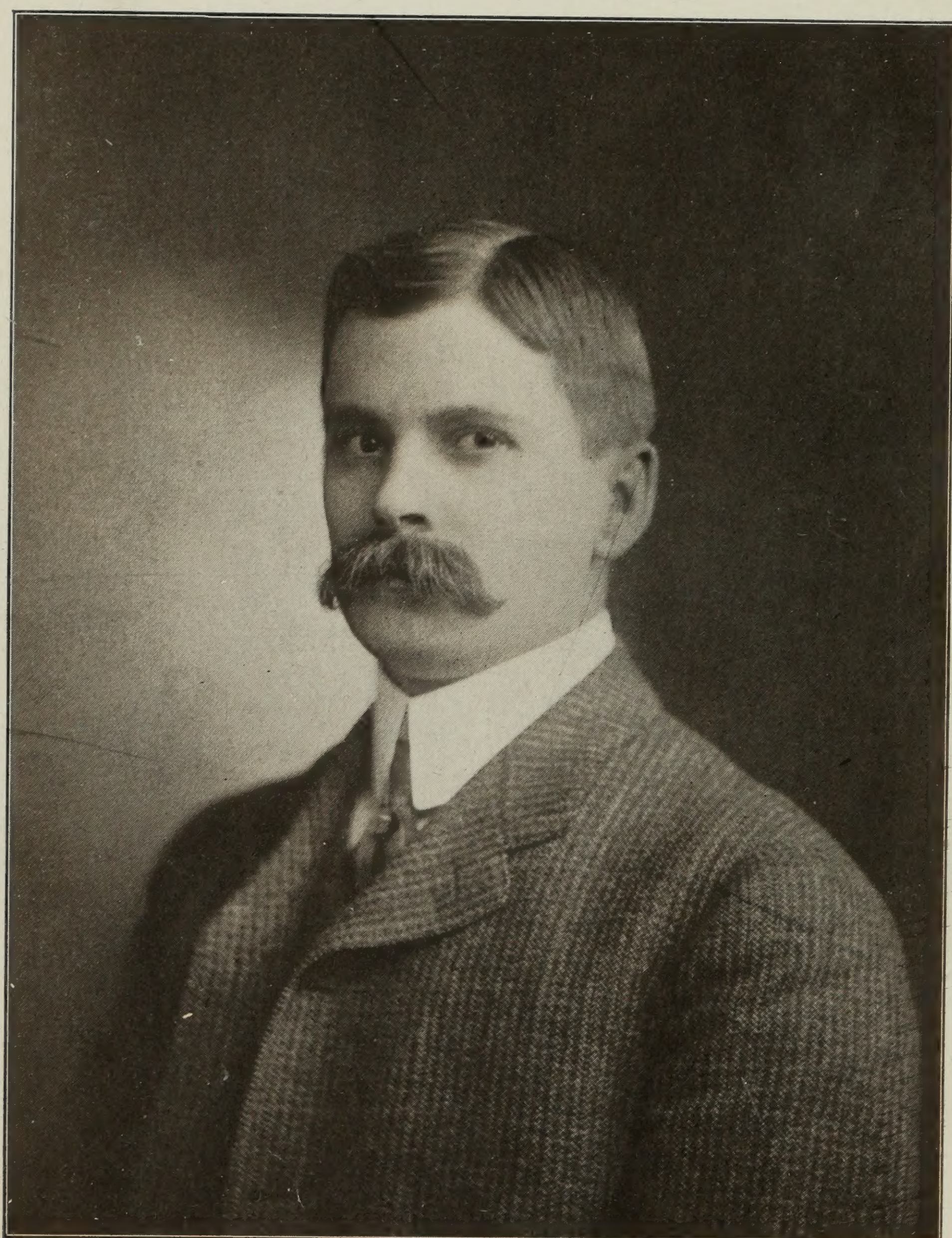
Frontispiece



Bion J. Arnold

PRESIDENT W. S. E. 1906

Vol. XI January to December 1906

# JOURNAL

OF THE

# WESTERN SOCIETY

OF

# ENGINEERS



PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS



CHICAGO
Published Bi-Monthly by the Society
1734-41 Monadnock Block

Subscription Price $3.00 Per Volume
of Six Numbers

# CONTENTS BY NUMBERS

VOL. XI.—JANUARY TO DECEMBER 1906

CONTENTS BY NUMBERS.

VOL. XI.—JANUARY TO DECEMBER, 1906.

No. 1.—January and February.

Page.

The Ownership of Public Utilities. Lyman E. Cooley .......... 1
Reports of a Test on a Portland Cement Plant. E. C. Soper .......... 8
The Prime Mover of the Future. Chas. E. Sargent .......... 35
Available Power and Cost of Operation of a Power Station for Waste Gases from a Blast Furnace Plant. H. Freyn .......... 65
The Lucin Cut-Off, U. P. R. R. (abstract) .......... 108
In Memoriam, Wm. H. Edgar .......... 109
Julian S. Hull .......... 110
L. S. Olmsted .......... 111
State Highway Commission—Open Letter .......... 112
Minutes of the Society .......... 114
Annual Reports .......... 117
Address of E. C. Carter, Retiring President .......... 122
Address of Bion J. Arnold, President-elect .......... 124
Book Reviews .......... 126
Library Notes .......... 131
Additions to Membership and Corrected Addresses .......... 134
List of Officers and Committees, 1906 .......... 136

No. 2.—March and April.

Waterways for Culverts and Bridges. G. H. Bremner and others .......... 137
Elevating and Conveying Machinery. S. F. Joor .......... 191
Standardization of Telephony. F. McBerty .......... 232
Illinois State Highway Commission .......... 245
Inland Navigation and Traffic Legislation .......... 246
Logarithmic Tables .......... 248
Fuel Tests; University of Illinois .......... 250
Minutes of Society Meetings .......... 251
Book Reviews .......... 255
Library Notes .......... 264
Additions to Membership .......... 267
Corrected Addresses of Members .......... 268

No. 3.—May and June.

Electric Street Cars for City Service. M. B. Starring and H. B. Fleming 269
Urban Tendencies of Population as affecting the problems of engineers. E. G. Smith .......... 297
A New Method of Calculating Bridge Stresses by Means of End Shears. W. T. Curtis and Josiah Gibson .......... 321
The Clay Slide at Boone (Iowa) Viaduct. A. W. Merrick .......... 332
Schools, Engineers and Employers. P. B. Woodworth .......... 351
Minutes of the Society Meetings .......... 369
Book Reviews .......... 372
Library Notes .......... 377
List of Officers and Committees .......... 380

## No. 4.—July and August.

High Pressure Sluicing Gates. M. O. Leighton........................ 381
What Degree of Accuracy is Feasible and Necessary in Wiring Calculations. Albert Scheible................................................ 391
Birth and Growth of the Steel Industry. James N. Hatch.............. 399
The Technolexicon. Report of Progress................................ 406
The Guatemala Railway. John Y. Bayliss............................... 407
The Hawthorne Shops of the Western Electric Co. H. R. King......... 413
The Assessment of Drainage Districts. L. E. Ashbaugh................ 433
Jefferson Street Bridge, South Bend, Ind. A. J. Hammond............. 453
In Memoriam, H. W. Parkhurst......................................... 470
Charles Paine......................................... 472
Minutes of Society Meetings.......................................... 474
Book Reviews......................................................... 475
Library Notes........................................................ 481
Additions to Membership.............................................. 484

## No. 5.—September and October.

Panama, Past and Present. W. J. Karner (abstract).................... 487
Development of Mechanical Filtration. R. E. Milligan................. 503
Some Characteristics of Coal as affecting performance with Steam Boilers. W. L. Abbott................................................ 529
The Proposed Inner Circle Systems of Chicago Subway Terminals. A. S. Robinson...................................................... 576
Minutes of Society Meetings.......................................... 624
Corrections and Additions to Membership.............................. 625
Book Reviews......................................................... 627
Officers of the Society.............................................. 628

## No. 6.—November and December.

Public Policy Demands a Waterway System. A Discussion............ 629
Notes on Road Resistance. C. H. Hudson............................... 660
Electric Power Systems in some European Cities. P. Junkersfeld....... 686
Suppression of Industrial Smoke, with Particular Reference to Steam Boilers. A. Bement................................................ 693
Testing of Coal. A. Bement........................................... 753
In Memoriam; John Saltar, Jr......................................... 793
Beneath the City of Chicago.......................................... 795
Waterways for Bridges and Culverts................................... 797
Society Notes; Minutes............................................... 799
Book Reviews......................................................... 808
Library Notes........................................................ 820
Membership—additions and corrections................................. 824
Officers and Committees of the Society...............................827-8

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1906



## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Electrical Section—S. G. McMeen, Chairman, generally the 2d Friday of the month, October to May, inclusive.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago.

## LIST OF OFFICERS FOR 1907

| | |
|---|---|
| President | W. L. ABBOTT |
| First Vice-President | ANDREWS ALLEN |
| Second Vice-President | E. N. LAYFIELD |
| Third Vice-President | A. N. TALBOT |
| Treasurer | A. REICHMANN |

## TRUSTEES

| | |
|---|---|
| G. M. WISNER | Term expires January, 1908 |
| JOHN BRUNNER | Term expires January, 1909 |
| W. C. ARMSTRONG | Term expires January, 1910 |
| R. MODJESKI, E. C. CARTER, B. J. ARNOLD | Past Presidents. |

**The above named officers of the Society and three past presidents, constitute its Board of Direction.**

Secretary and Librarian
J. H. WARDER

## COMMITTEES

*On Finance*—Andrews Allen, A. Reichmann, H. N. Elmer.

*On Publication*—E. N. Layfield, R. F. Schuchardt, L. K. Sherman, C. B. Burdick, O. P. Chamberlain, W. S. Monroe, J. W. Schaub.

*On Library*—John Brunner, C. H. Cartlidge, P. B. Woodworth.

*On Membership*—W. C. Armstrong, B. B. Carter, P. Junkersfield.

## THE ELECTRICAL SECTION

C. A. S. Howlett, Chairman, D. W. Roper, Vice-Chairman, for 1907.

| | |
|---|---|
| P. B. WOODWORTH | 1 year |
| O. E. OSTHOFF | 2 years |
| K. B. MILLER | 3 years |

*Members of Executive Committee.*

## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Electrical Section—C. A. S. Howlett, Chairman, generally the 2d Friday of the month, October to May, inclusive.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL.

# INDEX

Vol. XI—January to December, Inclusive,

1906.

A New Method of Calculating Bridge Stresses by Means of End Shears, by W. T. Curtis, M. W. S. E., and J. Gibson, M. W. S. E. .......... 321
Abbott, W. L.,, M. W. S. E., "Some Characteristics of Coal as affecting performance with Steam Boilers .......... 529
Additions to Membership and Corrected Addresses ......134, 267, 484, 625, 824
Alvord, J. W., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 159
Alvord, J. W., M. W. S. E., Discussion of R. E. Milligan's paper on "Mechanical Filtration" .......... 526
Annual Reports .......... 117
Arnold, Bion J., M. W. S. E., address as Persident-elect .......... 124
Arnold, Bion J., M. W. S. E., Discussion of A. S Robinson's paper on "Inner Circle System of Subway Terminals for Chicago" ........590, 606
Ashbaugh, L. E., M. W. S. E., "Assessment of Drainage Districts" ...... 433
Assessment of Drainage District, by L. E. Ashbaugh, M. W. S. E. ........ 433
Automobiles—Notes on Road Resistances, by C. H. Hudson, M. W. S. E. 660
Available power and cost of operation of a Power Station for waste gases from a blast furnace plant, by H. Freyn, M. W. S. E. .......... 65
Bain, H. Foster, M. W. S. E., Discussion of A. Bement's paper on "The Testing of Coal" .......... 766
Bain, H. Foster, M. W. S. E., Discussion of A. W. Merrick's paper on "Clay Slide at Boone, Iowa, Viaduct" .......... 338
Bayliss, John Y., M. W. S. E., "The Guatemala Railway" .......... 407
Bean, O. U., Discussion of A. Bement's paper on "Suppression of Smoke" 719
Bement, A., M. W. S. E., "The Testing of Coal" .......... 753
Bement, A., M. W. S. E., "Industrial Smoke Suppression, with particular reference to Steam Boilers" .......... 693
Bement, A., M. W. S. E., Discussion of W. L Abbott's paper on "Characteristics of Coal" .......... 556, 572
Beneath the City of Chicago, by E. C. Shankland, M. W. S. E. .......... 795
Birth and Growth of the Steel Industry, by James N. Hatch, M. W. S. E. 399
Blast Furnace Plant,—available power and cost of operation of a power station for waste gases from a blast furnace plant, by H. Freyn, M. W. S. E. .......... 65
Booth, William M., Discussion of A. Bement's paper on "The Testing of Coal" .......... 773
Breckenridge, L. P., M. W. S. E., Discussion of A. Bement's paper on "The Testing of Coal" .......... 764
Breckenridge, L. P., M. W. S. E., Discussion on W. L. Abbott's paper on Characteristics of Coal .......... 550
Bremner, G. H., M. W. S. E., "Waterways for Culverts and Bridges" .. 137
Bridge, (concrete) Jefferson St., South Bend, Ind., by A. J. Hammond .. 453
Bridge Stresses calculated by means of end shears (a new method), by W. T. Curtis, M. W. S. E., and J. Gibson, M. W. S. E. .......... 321
Boone (Iowa) Viaduct, Clay Slide at, by A. W. Merrick, M. W. S. E. .. 332
Brooks, Morgan, M. W. S. E., Discussion of Albert Scheible's paper on "Wiring Calculations" .......... 396
Burdick, Chas. B., M. W. S. E., Discussion of L. E. Ashbaugh's paper on "Assessment of Drainage Districts" .......... 450
Burdick, C. B., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 173

Calculating Bridge Stresses by Means of End Shears, by W. T. Curtis, M. W. S. E., and J. Gibson, M. W. S. E. .......... 321
Carter, E. C., M. W. S. E., Discussion of A. W. Merrick's paper on "Clay Slide at Boone (Iowa) Viaduct" .......... 337
Carter, E. C., Retiring President, address .......... 122
Cary, Albert A., Discussion of W. L. Abbott's paper on "Characteristics of Coal" .......... 562
Cement Plant (Portland), Reports of a Test on, by Ellis C. Soper, Jun. M. W. S. E. .......... 8
Chamberlain, O. P., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 175
Cheney, E. H., Discussion of A. Bement's paper on "The Testing of Coal" 770
Chicago Subway Terminals, "Inner Circle System," by A. S. Robinson, M. W. S. E. .......... 576
Clay Slide at Boone (Iowa) Viaduct, by A. W. Merrick, M. W. S. E. .......... 332
Coal, some Characteristics of, an affecting performance with steam boilers, by W. L. Abbott, M. W. S. E. .......... 529
Coal, Testing of, by A. Bement, M. W. S. E. .......... 753
Concrete Bridge at South Bend, Ind. (Jefferson St.), by A. J. Hammond 453
Conveying and Elevating Machinery, by S. F. Joor, M. W. S. E. .......... 191
Cooley, Lyman E., M. W. S. E., Discussion, "Public Policy Demands a Waterway System" .......... 629
Cooley, L. E., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 170, 175
Cooley, Lyman E., M. W. S. E., "The Ownership of Public Utilities" .......... 1
Cooper, W. F., Discussion of A. Bement's paper on "The Testing of Coal" 775
Corrected Addresses and Additions to Membership .......... 134, 268, 484, 625
Culverts and Bridges, Waterways for, by G. H. Bremner, M. W. S. E. .......... 137
Curtis, W. T., M. W. S. E., and J. Gibson, M. W. S. E., "A New Method of Calculating Bridge Stresses by Means of End Shears" .......... 321
Cut-off, Lucin, on U. P. R. R. (abstract by Prof. Albert Smith, M. W. S. E., Purdue) .......... 108
Damon, Geo. A., M. W. S. E., Discussion of Albert Scheible's paper on "Wiring Calculations" .......... 396
Darling, J. N., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 172
Denison, John P., Discussion of R. E. Milligan's paper on "Mechanical Filtration" .......... 521
Development of Mechanical Filtration, by R. E. Milligan, M. W. S. E. .......... 503
DeWolfe, E. C., M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers" .......... 364
Dowse, Thomas, Discussion, "Public Policy Demands a Waterway System" .......... 655
Drainage Districts, Assessment of, by L. E. Ashbaugh, M. W. S. E. .......... 433
Dun, James, M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 146
Duryea, Edwin, Jr., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 178
Edgar, Wm. H., Memorial .......... 109
Electric Power Systems in some European Cities, by P. Junkersfeld, M. W. S. E. .......... 686
Electric Street Cars for City Service, by M. B. Starring and H. B. Fleming 269
Elevating and Conveying Machinery, by S. F. Joor, M. W. S. E. .......... 191
Elliott, Frank, Discussion of A. Bement's paper on "Suppression of Smoke" .......... 702
Employers, Schools, and Engineers, by P. B. Woodworth, M. W. S. E. .. 351
End Shear Tables, calculating bridge stresses by means of, by W. T. Curtis, M. W. S. E., and J. Gibson, M. W. S. E. .......... 321
Engineers, Schools and Employers, by P. B. Woodworth, M. W. S. E. .. 351
Filtration, Mechanical, by R. E. Milligan, M. W. S. E. .......... 503

Fisher, Walter L., Discussion of A. S. Robinson's paper on "Inner Circle" System of Subway Terminals for Chicago........................ 592
Fitts, Edwin, Discussion of A. Bement's paper on "Suppression of Smoke" 715
Fleming, H. B., and M. B. Starring, "Electric Street Cars for City Service" 269
Fleming, H. B., Discussion of A. S. Robinson's paper on "Inner Circle" System of Subway Terminals for Chicago........................ 596
Fox, John A., Discussion, "Public Policy Demands a Waterway System" 653
Freeman, C. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers, and Employers"........................................ 360
Freyn, H., M. W. S. E., "Available Power and Cost of Operation of a Power Station for Waste Gases from a Blast Furnace Plant"........ 65
Fuel Tests at University of Illinois.................................... 250
Garden, Hugh R., Inland Navigation and Traffic Legislation. (Abstract.). 246
Gas Engines,—available power and cost of operation of a power station for waste gases from a blast furnace plant, by H. Freyn, M. W. S. E.. 65
Gas Engines: The Prime Mover of the Future, by Charles E. Sargent, M. W. S. E............................................................ 35
Gates, High Pressure Sluicing, by M. O. Leighton........................ 381
Gibson, Josiah, M. W. S. E., and W. T. Curtis, M. W. S. E., "A New Method of Calculating Bridge Stresses by Means of End Shears"..... 321
Goddard, W. L., Discussion of A. Bement's paper on "Suppression of Smoke" ............................................................ 703
Gray, J. C., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges"...................................... 169
Green, W. J., Discussion of A. Bement's paper on "The Testing of Coal" 778
Guatemala Railway, the, by John Y. Bayliss, M. W. S. E................ 407
Gudeman, Edward, Discussion of A. Bement's paper on "The Testing of Coal" ............................................................ 778
Hammond, A. J., "Jefferson Street Bridge at South Bend, Indiana".... 453
Harrington, Joseph, Discussion of A. Bement's paper on "Suppression of Smoke" ............................................................ 717
Harvey, Charles T., Discussion, "Public Policy Demands a Waterway System" ............................................................ 637
Hatch, James N., M. W. S. E., "Birth and Growth of the Steel Industry" 399
Hatch, J. N., M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers"............................... 399
Hawthorne Shops of the Western Electric Co., by H. R. King, M. W. S. E 413
"High Pressure Sluicing Gates." by M. O. Leighton..................... 381
Highway Commission, State (Illinois), an open letter..............112, 245
Himes, Albert J., Discussion of G. H. Bremner's paper on Waterways for Culverts and Bridges".............................................. 186
Howlett, C. A. S., M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers"............................ 357
Hudson, C. H., M. W. S. E., "Notes on Road Resistances"............ 660
Hull, Julian S., Memorial.............................................. 110
Illinois State Highway Commission................................112, 245
Industrial Smoke Suppression, with particular reference to Steam Boilers, by A. Bement, M. W. S. E..................................... 693
Inland Navigation and Traffic Legislation, by Hugh R. Garden: A review by Julius Stern, Assoc. M. W. S. E.................................. 246
Inner Circle System of Chicago Subway Terminals, by A. S. Robinson. M. W. S. E.......................................................... 576
Jefferies, F. L., M. W. S. E., Discussion of W. L. Abbott's paper on "Characteristics of Coal"........................................... 559
Jefferson Street Bridge at South Bend, Indiana, by A. J. Hammond..... 453
Joor, S. F., M. W. S. E., "Elevating and Conveying Machinery"......... 191
Junkersfeld, P., M. W. S. E., "Electric Power Systems in some European Cities" ............................................................ 686
Karner, W. J., M. W. S. E., "Panama, Past and Present"................ 487
Kent, William, Discussion of A. Bement's paper on "Suppression of Smoke" ............................................................ 724

Kent, William, Discussion of A. Bement's paper on "The Testing of Coal" 771
King, H. R., M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers" .......... 355
King, H. R., M. W. S. E., "Hawthorne Shops of Western Electric Co.".. 413
Kingman, Louis, Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 166
Kreisinger, Henry, Discussion of A. Bement's paper on "Suppression of Smoke" .......... 712
Kuss, Robert H., M. W. S. E., Discussion of W. L. Abbott's paper on "Characteristics of Coal," etc .......... 555
Leighton, M. O., "High Pressure Sluicing Gates" .......... 381
Library Notes .......... 131, 264, 377, 481, 820
Liljencrantz, G. A. M., M. W. S. E., Translation of Preface of Wiborg's Logarithmic Tables .......... 248
Logarithmic Tables, calculated and printed by machinery, by M. Wiborg. Preface of the book translated by G. A. M. Liljencrantz, M. W. S. E. 248
Loweth, C. F., M. W. S. E., Discussion of A. W. Merrick's paper on Clay Slide at Boone, Iowa, Viaduct .......... 335
Lucin Cut-Off on the U. P. R. R. (abstract by Prof. Albert Smith, M. W. S. E .......... 108
Machinery—Elevating and Conveying, by S. F. Joor, M. W. S. E .......... 191
McArdle, P. C., M. W. S. E., Discussion of W. L. Abbott's paper on "Characteristics of Coal" .......... 559
McArdle, P. C., M. W. S. E., Discussion of A. Bement's paper on "The Testing of Coal" .......... 769
McBerty, F., M. W. S. E., "Standardization in Telephony" .......... 232
McCullough, Ernest, M. W. S. E., Discussion of L. E. Ashbaugh's paper on "The Assessment of Drainage Districts" .......... 447
Mead, D. W., M. W. S. E., Dicussion of R. E. Milligan's paper on "Mechanical Filtration" .......... 514
Mechanical Filtration, by R. E. Milligan, M. W. S. E .......... 503
Memorials,
- William H. Edgar .......... 109
- Julian S. Hull .......... 110
- L. S. Olmsted .......... 111
- H. W. Parkhurst .......... 470
- Charles Paine .......... 472
- John Saltar, Jr .......... 793

Merriam, L. B., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 168
Merrick, A. W., M. W. S. E., The Clay Slide at Boone (Iowa) Viaduct.. 332
Miller, K. B., M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers" .......... 363
Milligan, R. E., M. W. S. E., "The Development of Mechanical Filtration" 503
Minutes of Society .......... 114, 251, 369, 474, 624, 799
Murphy, E. C., "Waterways for Bridges and Culverts," a letter .......... 797
Murphy, E. C., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .......... 148, 797
Notes on Road Resistances, by C. H. Hudson, M. W. S. E .......... 660
Noyes, W. A., Discussion of A. Bement's paper, 'The Testing of Coal".. 770
Officers and Committees, 1906 .......... 136, 380, 827, 828
Olmsted, L. S., Memorial .......... 111
Ownership of Public Utilities, by Lyman E. Cooley, M. W. S. E .......... 1
Paine, Charles, Memorial .......... 472
Panama, Past and Present, by W. J. Karner, M. W. S. E .......... 487
Parkhurst, H. W., Memorial .......... 470
Parr, S. W., Discussion of A. Bement's paper on "Testing of Coal" .... 761
Peabody, F. S., Discussion of A. Bement's paper on "Testing of Coal" ... 779
Population, Urban Tendencies of, as affecting the problems of engineers, by E. G. Smith, M. W. S. E .......... 297

Portland Cement Plant, Reports of a Test on, by Ellis C. Soper, Jun. M. W. S. E. .... 8
Power Plant, available power and cost of operation of a Power Station for waste gases from a blast furnace plant, by H. Freyn, M. W. S. E. 65
Power Systems (electric) in some European Cities, by P. Junkersfeld.. 686
Prime Mover of the Future (gas engines), by C. E. Sargent, M. W. S. E. 35
Proposed Inner Circle System of Chicago Subway Terminals, by A. S. Robinson, M. W. S. E. .... 576
Public Policy Demands a Waterway System, Discussion .... 629
Public Utilities, Ownership of, by Lyman E. Cooley, M. W. S. E. .... 1
Railway, the Guatemala, by John Y. Bayliss, M. W. S. E. .... 407
Ransdell, J. E., Discussion, "Public Policy Demands a Waterway System" 642
Ray, Walter T., Jun. M. W. S. E., Discussion of W. L. Abbott's paper on "Characteristics of Coal," etc. .... 546
Raymond, Francis, Assoc. M. W. S. E., Discussion of P. B. Woodworth's paper on "Schools, Engineers and Employers" .... 366
Reports of a Test on a Portland Cement Plant, by Ellis C. Soper, Jun. M. W. S. E. .... 8
Rice, E. S., M. W. S. E., Discussion of G. H. Bremner's paper on "Waterways for Culverts and Bridges" .... 171
Rice, Geo. S., M. W. S. E., Discussion of A. Bement's paper on "The Testing of Coal" .... 767
Road Resistances, by C. H. Hudson, M. W. S. E. .... 660
Robinson, A. S., M. W. S. E., "The Proposed Inner Circle System of Chicago Subway Terminals" .... 576
Saltar, John, Jr., Memorial .... 793
Sargent, C. E., M. W. S. E., "The Prime Mover of the Future" (Gas engines) .... 35
Saxe, A. J., M. W. S. E., Discussion of A. Bement's paper on "Suppression of Smoke" .... 707
Scheible, Albert, M. W. S. E., "Accuracy in Wiring Calculations" .... 391
Scholz, Carl, Discussion of A. Bement's paper on "Suppression of Smoke" 711
Schools, Engineers and Employers, by P. B. Woodworth, M. W. S. E. .... 351
Schubert, John C., Discussion of A. Bement's paper on "Suppression of Smoke" .... 722
Shankland, E. C., M. W. S. E., "Beneath the City of Chicago" .... 795
Shaw, W. A., M. W. S. E., Discussion of W. L. Abbott's paper on "Characteristics of Coal" .... 553
Sluicing Gates, High Pressure, by M. O. Leighton .... 381
Smith, Albert, M. W. S. E., Abstract of article by O. K. Davis in Century Magazine on "The Lucin Cut-off on the U. P. R. R." .... 108
Smith, E. G., M. W. S. E., "Urban Tendencies of Population as affecting the problems of engineers" .... 297
Smoke Suppression, with particular reference to Steam Boilers, by A. Bement, M. W. S. E. .... 693
Some characteristics of Coal as affecting performance with Steam Boilers, by W. L. Abbott, M. W. S. E. .... 529
Soper, Ellis C., Jun. M. W. S. E., "Reports of a Test on a Portland Cement Plant" .... 8
South Bend, Ind., Concrete Bridge, by A. J. Hammond .... 453
Standardization in Telephony, by F. McBerty, M. W. S. E. .... 232
Starring, M. B., Discussion of A. S. Robinson's paper on "Inner Circle" System of Subway Terminals for Chicago .... 592
Starring, M. B., and H. B. Fleming, Electric Street Cars for City Service 269
State Highway Commission (Illinois), open letter .... 112, 245
Steel Industry, Birth and Growth, by James N. Hatch, M. W. S. E. .... 399
Stern, Julius, Assoc. M. W. S. E., A review of a lecture on Inland Navigation and Traffic Legislation, by Hugh R. Garden .... 246
Street Cars (electric) for City Service, by M. B. Starring and H. B. Fleming .... 269

Strehlow, O. E., M. W. S. E., Construction of Jefferson St. Bridge at South Bend, Ind. .......... 462
Suppression of Industrial Smoke, with particular reference to Steam Boilers, by A. Bement, M. W. S. E. .......... 693
Subway Terminals, Chicago, Inner Circle System, by A. S. Robinson, M. W. S. E. .......... 576
Talbot, Arthur N., M. W. S. E., Discussion on "Waterways for Culverts and Bridges" .......... 183
Taylor, E. H., Discussion of A. Bement's paper "Suppression of Smoke" .. 714
Taylor, Edward H., Discussion of W. L. Abbott's paper on "Characteristics of Coal" .......... 555
Technolexicon .......... 406
Telephony, Standardization in, by F. McBerty, M. W. S. E. .......... 232
Terminals, Subway,—Proposed Inner Circle System for Chicago, by A. S. Robinson, M. W. S. E. .......... 576
Testing of Coal, by A. Bement, M. W. S. E. .......... 753
Tratman, E. E. R., M. W. S. E., Discussion of A. W. Merrick's paper "Clay Side at Boone, Iowa, Viaduct" .......... 336, 339
Urban Tendencies of Population as affecting the problems of engineers, by E. G. Smith, M. W. S. E. .......... 297
Wagner, Walter, M. W. S. E., Discussion on Mechanical Filtration .......... 524
Waste gases,—available power and cost of operation of a power station for waste gases from a blast furnace plant, by H. Freyn, M. W. S. E. 65
Waterway System, Public Policy Demands a—Discussion .......... 629
Waterways for Bridges and Culverts, a letter, by E. C. Murphy .......... 797
Waterways for Culverts and Bridges, by G. H. Bremner, M. W. S. E. .... 137
Western Electric Company's Hawthorne Shops, by H. R. King .......... 413
Weston, C. V., M. W. S. E., Discussion of A. S. Robinson's paper on "Inner Circle" System of Subway Terminals, for Chicago .......... 592
Weston, George, M. W. S. E., Discussion of A. S. Robinson's paper on "Chicago Subway Terminals" .......... 597
What degree of Accuracy is feasible and necessary in wiring calculations, by Albert Scheible, M. W. S. E. .......... 391
Wiring Calculations, degree of accuracy, etc., by Albert Scheible, M. W. S. E. .......... 391
Woodworth, P. B., M. W. S. E., Schools, Engineers and Employers .... 351
Zinn, A. S., M. W. S. E., Discussion of A. W. Merrick's paper on "Clay Slide at Boone, Iowa, Viaduct" .......... 337

Book Reviews.

Adjustments of the Engineer's Transit and Level, by H. C. Ives .......... 373
Analytical Chemistry—Qualitative and Volumetric, by John H. Long ... 815
Batter Tables, by C. G. Wrentmore .......... 810
Berlin-Zossen Electric Railway Tests of 1903, by Franz Welz and Louis Bell .......... 126
Business of Contracting, the, by Ernest McCullough .......... 376
Cathechism on Producer Gas, by Samuel S. Wyer .......... 814
City Roads and Pavements, by W. P. Judson .......... 478
Corrosion and Protection of Metals, by A. H. Sexton .......... 479
Disinfection and Disinfectants, by M. J. Rosenau .......... 130
Electric Power Transmission, by Louis Bell .......... 259
Electric Transmission of Water Power, by A. D. Adams .......... 476
Elements of Gas Engine Design, by Sanford A. Moss .......... 815
Elements of General Chemistry, by John H. Long .......... 815
Five Figure Logarithms, by Henry Harrison Suplee .......... 812
Fowler's Architects' and Builders' Handbook .......... 814
Fowler's Electrical Engineers' Year Book and Directory of Light, Power, and Traction Stations .......... 257
Fowler's Mechanical Engineers' Pocket Book for 1906 .......... 372
Gas, Gasoline and Oil Engines, by G. D. Hiscox .......... 126

General Specifications for Steel Railroad Bridges and Structures, by A. W. Buel .......... 627
General Specifications for Steel Railroad Bridges and Viaducts, by Theodore Cooper .......... 808
Gold Dredging, by C. C. Longridge .......... 128
Gold Dredging, annual supplement for 1906, by Longridge .......... 374
Handbook of Mathematics for Engineers and Engineering Students, by J. Claudel .......... 814
High Tension Power Transmission, Vol. I., by McGraw Publishing Co. . 127
High Tension Power Transmission, Vol. II., by McGraw Publishing Co. . 477
Illustrated Technical Dictionary, by K. Deinhardt and A. Schlomann .... 811
Indicator Handbook, by C. N. Pickworth .......... 372
Machine Tools, by Thomas R. Shaw .......... 131
Manufacture of Concrete Blocks, and their use in Building Construction, by H. H. Rice .......... 373
Manual of Field Engineering, by H. C. Ives and Harold Ezra Hilts ...... 809
Mechanics of Road Construction, by H. P. Gillette .......... 810
Modern Machine Shop, Construction, Equipment and Management, by O. T. Perrigo .......... 255
Modern Tunnel Practice, by D. M. N. Stauffer .......... 263
Notes on Electro-Chemistry, by F. G. Wiechmann .......... 375
Outlines of Practical Sanitation for Students, Physicians, and Sanitarians, by Harvey B. Bashore .......... 813
Plumbing Catechism, or Theory and Practice of Plumbing Design, by Chas. B. Bell and H. T. Sheriff .......... 627
Practical Alternating Currents and Alternating Current Testing, by C. F. Smith .......... 260
Practical Cement Testing, by W. Purves Taylor .......... 261
Practical Electrical Railway Handbook, by A. B. Herrick .......... 256
Practical Pattern Making, by Herbert Aughtie .......... 262
Practical Pattern Making, by F. W. Barrows .......... 127
Practical Testing of Dynamos and Motors, by C. F. Smith .......... 478
Principles and Practice of Surveying, by Charles B. Breed and Geo. L. Hosmer .......... 809
Putnam's Monthly .......... 816
Shaft Governors, by Trinks and Housum .......... 375
Smoley's Tables, by Constantine Smoley .......... 374
Standard Reduction Factors for Gases, by H. B. MacFarland .......... 129
Standard Telephone Wiring, by Fairman .......... 259
Steam Turbines and Turbo Compressors, their design and construction, by Frank Foster .......... 812
Stray Currents from Electric Railways, by Carl Michalke, translated by Otis Kenyon .......... 811
Tin Deposits of the World, by Sidney Fawns .......... 129
Types and Details of Bridge Construction, Part 2, by F. W. Skinner .... 475
Universal Dictionary of Mechanical Drawing, by Geo. H. Follows ........ 816
Ventilation of Buildings, by W. G. Snow .......... 262
Wiring Handbook, by Cecil P. Poole .......... 261

Journal of the

Western Society of Engineers

VOL. XI. FEBRUARY, 1906. NO. 1.

# THE OWNERSHIP OF PUBLIC UTILITIES.

LYMAN E. COOLEY, M. W. S. E.

*An Address at the Annual Meeting of the Society, Jan. 2, 1906.*

I am reminded of a remark once made by a senator who said that "when Captain Eads talked about things which he knew, he was profoundly interesting, but he persisted in talking about things of which he was learning." The subject of public ownership is something about which we have been learning ever since men gathered together. The problem is before us today in its varied phases, and has yet to be solved.

I have considered that it would not be proper, before the Western Society of Engineers, to go into the merely political side of the question, nor to treat it from the standpoint of a partisan, but rather to approach it from the politico-economic side. As I reflected upon this question, I became profoundly impressed, and although I prepared some notes, I find it necessary in the brief time at my disposal, to throw them away and treat the subject in the air,—to make a historical and geographical outline or sketch, as it were.

## THE PROBLEM OF MANY GOVERNMENTS.

"We can tolerate neither the evils we suffer, nor the remedies to cure them." So wrote Titus Livius of the age of the Caesars,—Julius and Augustus.

Rome had grown rich through military conquest and the exploitation of new lands. The capital was the seat of commerce and industry, the abode of luxury and predatory wealth, and classes had grown up with labor guilds at war with the ruling elements. Julius Caesar sought to extend the franchise from the narrow Roman state throughout the Italian Peninsula in order to curb the power of the growing domination and out of the struggle between mass and class came the dictator and the assassin. Augustus sought reforms about which everybody agreed, but which were resisted by every one when applied to himself, and each effort only left conditions worse than before. Political activity blighted in non fulfillment the military spirit decayed, gradual dissolution set in,

to be arrested at intervals by some brilliant Caesar, born in the newer life of the provinces.

In all history, and in some disguise, it has been the struggle of the man who has not against the man who has, for a better distribution of the bounties of nature and the rewards of effort, and though we inch along, the problem in its essence is unsolvable. The ancient kingdom was a city with its supporting territory and in time, wealth and power concentrated in the few and tempted the robber—war; and there was always a class ready to open the city gates, for out of the destruction and the loot, something came to them, so they could start again on a more even footing.

The purely commercial and industrial nations have been short-lived. Study the history of Tyre, Carthage and Alexandria; of Rome itself in its industrial aspect, of Byzantium and of Venice; of Spain, the Netherlands, and even England itself, and there are others. The mass comes to depend on the few and with the loss of individualism goes the sterner virtues.

England, like ancient Rome, has sought to govern the world from the narrow confines of an inferior state, to substitute the accumulated wealth of commerce and industry for the actual riches of material resources and of men. America gained independence and the other colonies have secured autonomy, the half-way house to independence. The growth of rivals and the shrinking of revenues, the slow wasting of accumulated wealth when not constantly replenished, perhaps coupled with disastrous wars, is the post-road along which her kind has swiftly passed.

The cyclone sweeping Russia expresses conditions that are far from new; the state organizes industrialism and forthwith inaugurates strife between organized labor and wealth and privilege, and all the centrifugal elements of society are turned loose. In Germany the Kaiser sits on the safety-valve, and when and where he will get off, nobody knows. France has exploded more than once in modern times and rebuilt more wisely for the commen good. We have troubles of our own, and a President who talks much thereof.

EPOCH OF DISCOVERY AND INVENTION.

In all history, someone has foreseen wisely, but too often institutions have been too rigid to make changes without violence and perhaps annihilation. Are the institutions of our own land sufficiently plastic to respond to the evolution of human conditions?

Inspired by French idealism as to the "rights of man," our forefathers sought to establish a representative government based on individualism. These institutions seemed adapted to the social and economic conditions of that period, but they had hardly confirmed themselves in the lives of two or three generations, had hardly ceased to be experimental, before a change in conditions arose, a change greater than had occurred throughout recorded history.

Beginning largely in the second quarter of the century just passed and swelling in multiple ratio in its last half, came the era of discovery and invention. In "Conservation of Energy" was established the mutuality of all forces in nature. Transportation on water and land, by steam and electricity, and communication by wire and cable, and without either, these have broken down barriers, local, state and national, and made the world small. Power developments, metallurgy and industrial inventions, have revolutionized the mechanic arts and handicrafts. The change in method in forest, mine and field, in effect, constitutes a new creation. The sciences have been born and new arts have come forth. The care of life, the rules for living and the social order have greatly changed.

The growth of industrialism and of public utilities has produced great organizations and combinations of capital, with revenue powers beyond the dreams of government itself. All this was not foreseen and provided for, we are amazed at what develops from day to day, and the dominant note of the situation becomes labor organization, or unionism, combined with or arrayed against invested wealth, with neutral onlookers paying the freight in either case. The government itself, at least in part, becomes an expression of organized units rather than of collective individualism, and the strife is on.

GROWTH OF PUBLIC FUNCTIONS.

Socialism conveys to the Anglo-Saxon instinct an ugly meaning. The Latin and Slav formulates his paper programs and tests the issues in revolution. Anglo-Saxon institutions halt and inch along, correcting abuses, and evolving step by step under new conditions, abandoning nothing that is good or workable, not swallowing experience in idealism. Nevertheless, the last century records great changes and adaptations, so great that the road to some destination seems shorter than the way by which we have come.

Light house and port dues of all kinds soon disappeared and light houses, charts and all aids to navigation and free harbors, were soon provided at the public expense and this policy has even been extended to the public ownership of water front and docks, as in New York.

In the first decade, the State of New York granted to Livingston and Fulton the exclusive right to navigate the Hudson River by "fire and steam." Following down the century, the United States Supreme Court, by a series of decisions, has established the public character of all natural waterways, even to the limit of navigation by saw-logs and fish; and has recognized the public character of all waters in arid and semi-arid regions.

River and other improvements and canals, for free navigation and at the public expense, have become a part of a growing public policy. The embankment of land against overflow, the development of arid lands by irrigation, the restraint of floods by reservoirs and the conservation of waters by forest reserves, the protection and de-

velopment of fisheries, the fostering of agriculture, mining and the arts, national quarantine, weather and crop service, are all developments of the century.

The postal system has grown to rural free delivery to every householder throughout the land, and in some countries has taken over the telegraph and telephone, the package express and the savings bank.

The toll-road, bridge and ferry disappeared and public parks, boulevards, sewerage systems and public sanitation, hospitals and charities have been established; and water works and water supplies have largely passed to public ownership.

Public baths, tenement houses, old age pensions and insurance, have even taken root in foreign lands.

Our constitution and laws recognize individual ownership in land only, and no corporation has a right to hold more than is needed for corporate purposes.

The fundamental right of the state to control and regulate corporations and their earnings is fully established.

The education of the young has come to be regarded as peculiarly a state function, and even goes to the point of compulsion and interference with parental control. This is an outgrowth of scarcely half a century, and the human mind can hardly conceive a more radical invasion of personal rights and sacred relations in the interests of the common welfare.

What is done by the state along what may be called socialistic lines, is vastly stimulated and added to by private efforts and munificence.

We have come a long way in the past century and how far are we to go in the present century? Where have we drawn the line between the benefits provided from the public purse and those supplied by organized capital? Is it not where a specific return or earning in kind comes back to the investor; and are we quite rational in assuming and fiercely contending that public utilities that pay should be controlled by corporations, while the non-paying utility is reserved for the tax-payer? Is it not, after all, largely a matter of expediency, to be decided from time to time according to the exigencies in each case?

In the past we have relied upon competition and the common-law right to regulate rates on the basis of a reasonable return on the proper investment, to protect the public from exorbitant charges for necessary service. Is it true that this theory is not workable and is no longer tolerable, and must we fly immediately to the remedies that are not properly established in Anglo-Saxon experience and governmental systems?

## FIRST PRINCIPLES—THE SOVEREIGN.

Let us consider for a moment the fundamentals of our system,—look into the substance of things with the X-ray of the Engineer.

The state is sovereign, and the people are the state,—in other words, sovereignty vests in the people. They choose to limit their agents and representatives by a written constitution and to delegate certain functions which pertain alike to other states, to a general government. This delegation can be changed by consent of the union of states, and the state itself can change its own constitution outside of the delegated functions. In the last analysis, the sovereign is the aggregate opinion of the majority which is prepared to enforce its views.

All properties and rights pertain to the sovereign and of none of these can he divest himself, for that would destroy sovereignty in its essence. The citizen is guaranteed certain privileges in property—what Samuel J. Tilden called the "usufruct"—and of these he cannot be divested except by due process of law and just compensation; and what disposition shall be made of this property after death, is solely a matter of statutory regulation. The General Assembly can say at its next session that all property shall revert to the state on the decease of its possessor. The same is true of an artificial person, a corporation with a fixed term of life.

The state has for its own purposes, chosen to create certain agencies designated as quasi-public corporations and popularly known as "public utilities;" such as common carriers for transportation and communication, and service corporations for lighting, heating and power. In the fundamental sense, the managers of these agencies are state officers and responsible for the proper conduct of the agency, and can collect only such revenues for service rendered as are essential to conduct the business and make a reasonable return on the proper investment in the agency. By proper procedure the state can reclaim the agency at any time and it reverts at the expiration of the time limit.

The basal thought in all this is that there is no such thing as an indefeasible right, and that the will of the people when properly expressed is absolute, for that is the expression of sovereignty, and further, such sovereignty may express itself in times of distress and emergency in disregard of all forms and codes. When we go back to the fundamental principles, so-called socialism is not in it and designates merely a class who are little acquainted with the genius of our institutions. What we shall do from time to time is a matter of expediency for the common welfare, even to a change in the system of government itself.

### THE REMEDY.

The problem of the day and of the century now opening, is how to better distribute and equalize the benefits of the great discoveries and inventions of the last seventy years, and those to follow, which have made this the most singular epoch in the world's history. This problem must be solved, and solved on the side of the maintenance of individualism, or the very genius of our institutions will be sapped at its vitals. The alternative is a feudal sys-

tem more cruel than any in history, with lapses of chaos and eventual degeneration. It is the old story of government run by its special beneficiaries and creatures, and of unlicensed industrialism and commerce, that has perplexed good men throughout history from Julius and Augustus Caesar down to our own President; that produced a Napoleon, that has made the Kaiser the busiest man in Europe, and has put Witte astride the storm.

In view of some distinguished failures, and others still wrestling, I do not expect to settle this whole problem tonight. How and when it will be settled, I do not know, and I much suspect that there will be problems as long as men organize in government and fail to be born with equal endowments; nevertheless, as we range over intervals of time we find progress even in governments.

I do not believe, as a student of history nor as a civil engineer, that we can turn the wheels of the mill with the waters that have gone by. We can, however, change conditions for the future. We may call in the police power to deal with what we have with us, but statesmanship deals with what is to come.

We have been careless in constituting our public utility agencies and more careless in their supervision but what the future had to bring forth no one could foresee and public convenience seemed urgent. The abuses have become serious and the fundamental law, lying under contracts, permits and franchises, is invoked for redress. The remedy is uncertain and halting and beyond an amelioration we must permit the equities to work out and change conditions for the future.

There is, however, sufficient outlet for all the taxes we choose to raise and the sentiment for public ownership, in the undeveloped utilities about which there is no difference of opinion as to their public character, and out of these we may eventually get some corrections pending the death of existing agencies.

I would produce a system of free waterways, not less than 25,000 to 30,000 miles are feasible, on the largest scale of magnitude that the physical conditions will invite or permit. We cannot realize our economic destiny without cheaper rates for transporting much of our products and over our continental distances. Railway rate regulation cannot reach this, for it affects only that third of the gross earnings above operation and maintenance; but the new competitor is a rate regulator in itself and also stimulus to high class traffic from the enhanced prosperity. I believe the seaboard must go to the interior if we are to stand on a par with other continents in the future, and further in order to prevent over-concentration of urban population at the coast line.

We should be wisely forehanded about our water power development and electrical transmission. There is enough water power capable of development to turn every wheel, and to heat the houses and cook the food where fuel is expensive, for all the people who can live on the soil of the United States. Such power is akin to a

fundamental resource like the air and the water and it will lie closer to public necessity than gas or electric light plants. This matter, now in its infancy, should be taken in hand and out of it will come incidental regulation in many directions.

There are other avenues along which we may act wisely for the future, and while existing utilities are working out their equities, we can be forehanded against the time when the agency is to be relinquished or changed for the better. We may need some regeneration, however, in our theories and practices of office-getting and office-holding, before we can do more than to shut the barn-door after we find what comes out.

CONCLUSIONS.

Make operative the laws we have, regulate wisely as we can and provide for a new order as existing equities work out. Meantime, anticipate and develop new utilities so as to avoid repeating evils now complained of.

I am an optimist, though I foresee neither the time nor the nature of the millennium. Our political system has evolved rapidly but the material and social pace has been still more giddy and even somewhat disconcerting.

The socialistic (so-called) movement which seems now so rampant, is due more to the determination of the people to boss the situation than to any economic principles or socialistic dogmas, a determination to subdue corporations drunk on ill-gotten wealth. For this feeling the special beneficiaries of governmental policies have only themselves to blame.

I do not deprecate the socialist. In a government like ours, we need political activities of every class for the fullest discussion of every problem that arises and in the solution we care little what trade-mark or brand is applied. We need not be greatly worried over the noise, for that only indexes our style of debating important issues and the greater the vehemence, the sooner the question is tried out.

Of one thing I am certain, and that is, that matters in the long run, will work out as the positive majority shall wish them, and under our institutions, that is the standard of right. Individualism and responsible representation will prevail, for they are the basal elements in our system, and should it be necessary, every public utility will pass to the state, coal and iron mines included, every industry depending upon government favor will disappear, and our whole system of industrial organization and responsibility will be recast.

We shall remain a nation of freemen, with some doubts at times as to the definition. That is the real issue, as in the past, and we shall care little under what banner the contest is waged. *Vox populi vox Dei*, simply means that the majority is supreme and when it ceases to be, there will be chaos and an end to things.

# REPORT OF A TEST ON A PORTLAND CEMENT PLANT.

By E. C. Soper, Jun. M. W. S. E.

*Presented Nov. 15, 1905.*

## Introductory.

Manufacture of Portland Cement:*

It is barely possible there are a few members present who have not had occasion to investigate the Portland cement industry thoroughly, and with the permission of the others I think it advisable to devote a few remarks to its history, growth and extent in general, and a brief description of a typical plant.

Portland cement was first manufactured by Joseph Aspdin, an Englishman, in the year 1824. The process was patented but owing to his inability to secure financial support, further progress was delayed for some time. By his method chalk was mixed with clay, burned at a clinkering temperature, and the resulting material ground. When mixed with water and sand this cement set hard, and because of its similarity in appearance to the famous Portland building stone of England, the material was called Portland cement.

Technically described, Portland cement is a tri-silicate of calcium, alumina and iron burned to a point of vitrification, and then ground to a fine powder.

As in all industries, the original processes were crude, and even up to within the last few years, little attention was given to the improvements of the old system; in actual instances there are building today at least two plants in this country along the same lines as those constructed during the first years of experimentation.

The Germans were the first to thoroughly investigate this subject and produce Portland cement as a commercial article, and in consequence the industry has grown in that country to such an extent that at the present time an over production exists.

In the original plants, in fact in 80 per cent. of the present plants of Europe, vertical kilns were and are used. The first plants built in the United States were duplicates of the German plants, but because of the high price of labor and the low price of fuel in this country, as compared with the prevailing conditions in Europe, it was necessary for the Americans to perfect the German system. The most marked change which resulted was the substitution of the

---

*See the "Journal," June, 1901, for illustrations of Kilns and machinery for the manufacture of Portland cement.

rotary kiln for the vertical kiln. Right here is the economic theory for the use of the rotary kiln in preference to the English or vertical kiln.

First: The English or vertical kiln has a greater fuel efficiency than the rotary kiln, as it requires about 40 pounds of coal to burn one barrel of cement with the vertical kiln while it requires from 100 to 150 pounds of coal to burn one barrel of cement in the rotary kiln. But in the case of the vertical kiln, the raw material must be made up in the form of briquettes and placed in the kiln, and after being burned a certain time taken out. This is all accomplished by hand labor, and the resulting product is not uniform in quality, there being much under-burned and some over-burned clinker.

The Americans were the first to improve the system of manufacture. The first rotary kiln was 30 feet in length and 5 feet in diameter. This length was increased to 60 feet, and up to the last two or three years no further improvements were made at this point: the price of cement was from $2.00 to $3.00 per barrel, and the attention of the manufacturer was directed more particularly to capacity than to cost of production.

With but few exceptions the location and establishment of a Portland cement plant has been as follows; some man discovers that he has a deposit of clay or limestone or marl on his land; he interests some financial relatives or friends, and samples of the material are analyzed and reported upon. Out of every twenty such beginnings probably one plant is built. It has been the rule hitherto for the site to seek capital, rather than the better and more American method of capital seeking the site.

One of the important factors which has militated against the growth and success of the industry is the fact that business men invest their money in propositions absolutely without merit. The originator sells his land at a very high price, the plant is not a success and capital becomes skeptical. We have found that a proposition, in order to be a success in every sense of the term, must possess the following five requisites, and a careful consideration must be given the subdivision:

1. Market
    - Extent
    - Demand
    - Competition
        - Scattered
        - Concentrated
2. Raw Materials
    - Physical structure
        - Limestone

Shale
Marl
Clay
Quality
Quantity
Accessibility
Exposed
Overburden, and extent of,
Mined
Relative location
Together
Elevation
Permitting gravity system
Railway below.

3. Fuel
Kind
Gas
Coal
Oil
Cost
Supply
Heat value

4. Water
Quantity
Quality
Location

5. Transportation
Two Railways—trunk lines
Extent of territory covered.

Secondary importance.
Labor
Cost
Union or non-union
Living conditions
Experience

The cost of a strictly up-to-date cement plant is a much discussed question, but we have found, through our own experience and the experience of others, that a plant that will average one thousand barrels per day of 24 hours, or 350,000 barrels per year, allowing for repairs and shut-downs, costs from $400,000 to $550,000. The variation in price is due to the local conditions, price of cement, sand, labor, etc.

There are in the United States today about 60 Portland cement plants operating on one of the following four systems:

1. Wet process,—Materials; marl and clay or shale.
2. Semi-wet process,—Materials; limestone or chalk and shale or clay.
3. Dry Process,—Materials:
    - A. Limestone and shale or clay.
    - B. Argillaceous limestone, limestone or clay.
4. Miscellaneous,—Materials:
    - A. Furnace slag and lime
    - B. Soda ash-waste and clay.
    - C. Furnace slag and limestone.

1. Wet Process: Throughout Michigan, Indiana, Ohio, and Wisconsin there are many lakes containing a deposit of calcareous matter in the form of gray mud or "muck", which has been deposited by waters carrying calcium carbonate in solution, or by the remains of fresh water shells and animals. This "marl" contains from 50 per cent. to 70 per cent. of water, and is excavated by means of dredges, and is mixed wet with pulverized clay or shale. It is thoroughly agitated in tanks, ground in tube mills or ball mills and handled generally as a liquid by pumps to the kilns.

2. Semi-wet Process: Probably two out of all the plants in this country use this system, and these are located in Kansas. The limestone and shale are crushed, properly proportioned, and pulverized; 30 per cent. water is added, and the material fed into the kilns as a slurry.

3. Dry Process: A. Limestone and shale or clay. This system is the same as the semi-wet system, except no water is added to the raw materials which are fed into the kilns in a dry, powdered form.

B. Argillaceous limestone with limestone or clay. This system prevails in the Lehigh Valley district, where the raw material occurs in the form of an argillaceous limestone, which is a limestone containing a high percentage of silica and alumina. This percentage varies and clay or limestone is added in small percentages to make the proper proportions. In the purer limestone about 25 per cent. shale is added to 75 per cent. limestone.

4. Miscellaneous. A. Slag and limestone. From many of the iron furnaces the slag is being used with a certain proportion of limestone, the two being thoroughly mixed and ground. The resulting product is not a high grade Portland cement, but can be used for many purposes, though its use is not advisable, except for work below ground, under uniform conditions as to temperature and moisture.

B. Soda-ash waste and clay. There is but one plant in this country operating on these materials. This plant utilizes waste soda-ash containing lime, and by mixing with a certain proportion

of clay and burning, a good grade of Portland cement is produced.

C. Furnace slag and limestone. Ground and burned. Resulting product is good grade Portland cement.

When the prices of Portland cement were high, nearly all of the plants were successful, but when prices dropped it became necessary, especially for the marl plants, to investigate the problem of reducing the manufacturing cost. Many of the plants failed, as the cost of manufacturing equaled, and in many respects exceeded, the selling price. The difference in cost between the marl plants and the dry process plant is about 30 to 40 cents per barrel, because of the distance from the fuel supply and the amount of water to be evaporated by the marl plants.

Description of a typical plant: Dry process.

The limestone and shale are quarried, conveyed and elevated to rock crushers for reduction, and from whence the materials are proportioned, dried in rotary dryers, elevated to pulverizers, and conveyed to the rotary kilns in which it is burned to a clinker. Discharged from the rotary kiln into rotary clinker-coolers, it is then conveyed and elevated to pulverizers and thence conveyed to warehouse bins for storage, to be afterwards sacked by sacking machines and loaded into cars.

Fuel for burning: If coal is used it is dried, pulverized and blown by an air jet into the discharge or furnace end of the kiln, where the combustion forms a flame of high temperature.

In all the plants the prevailing kinds of grinding machinery are the ball and tube mills and the Griffin mills. Each system has its merits and defects, and it is not our intention to discuss them at this time. The theory of the ball and tube mill system is as follows: The clinker or raw material is fed into the ball mill which is a cylinder about 8 feet in diameter by 4 feet in length, containing a certain amount of steel balls. This cylinder revolves on its longitudinal axis; the material is ground by the balls and passes through screens in the perimeter of the mill. These screens are generally of 20 mesh to the linear inch. The product from this mill is fed into the tube mill, which is a 22 ft. cylinder, 5 ft. in diameter, nearly filled with 2½ in. flint pebbles. As the cylinder revolves, the material is ground by the pebbles and passes through a screen in the end of the tube. The Griffin mill consists of a vertical shaft supported at the upper end and having attached to the lower end a cylindrical casting. This casting revolves within a steel die or ring and by centrifugal force is carried against the inside of this ring. The material is fed into the top and ground between the ring and the suspended weight.

Comparison of processes: The Lehigh district is unique in the cement industry. The rock or argillaceous limestone prevails in no

other part of the United States. The district is already filled with mills and the investor must look to other localities for a field. A majority of the plants, and the ones typical of the industry, are those operating on limestone and shale. These are independent materials. and it has been proven by repeated experiments that the finer the raw material is ground and the more intimately mixed, the better will be the resulting product. In the dry process plant it is necessary to reduce the raw materials to such a fineness that 92 per cent. to 95 per cent. will pass through a 100 mesh screen.

The first object of a Portland cement mill is to produce Quality; the second is Quantity.

In the semi-wet process plant the raw material is pulverized so that 88 per cent. passes throuh a 100 mesh screen, and the material is then mixed thoroughly with 30 per cent. water, or such an amount that the material will just flow. This *slurry* burned to a clinker will furnish a cement which will be absolutely uniform in quality. The cost of the increased amount of fuel necessary to evaporate the water added, about balances the value of the small percentage of dust blown up the stack in the dry system, and the increased amount of power necessary to reduce the raw material to a fineness that from 88 per cent. or 92 per cent. to 95 per cent. will pass through a 100 mesh screen. This theory is further illustrated by the following simple example: Take three sacks of flour and one sack of buckwheat meal, mix thoroughly and for some time, and yet the resulting mixture will be streaked and not uniform in color throughout, but if the wheat and buckwheat be mixed and ground together, the resulting flour will have a uniform color.

During the last few years every department in the manufacture of cement has received the attention of engineers, and in many instances valuable improvements have been made, but the one stage which has probably received the most attention, and which will still admit of further improvement is the process of burning or clinkering.

Rotary kilns have been designed and built, varying in length from 60 feet to 150 feet, and with a diameter of from 4 ft. to 8 ft. It has been fully demonstrated that the 60 ft. kilns require more fuel per barrel of cement, whether coal, gas or oil be used as fuel, than the 100 ft. kiln.. The capacity has increased and the fuel consumption decreased with the increase of the diameter of the kilns within certain limits.

By repeated experiments and calculations we have determined that this proper length is from 100 ft. to 125 ft. and a diameter from 7 ft. to 9 ft., and that the straight kiln produces from 20 per cent to 30 per cent. more clinker than the tapered or bottle neck kiln. In actual practice, in the same plants, working on the same

materials, using the same fuel and under the same conditions, these statements have been verified.

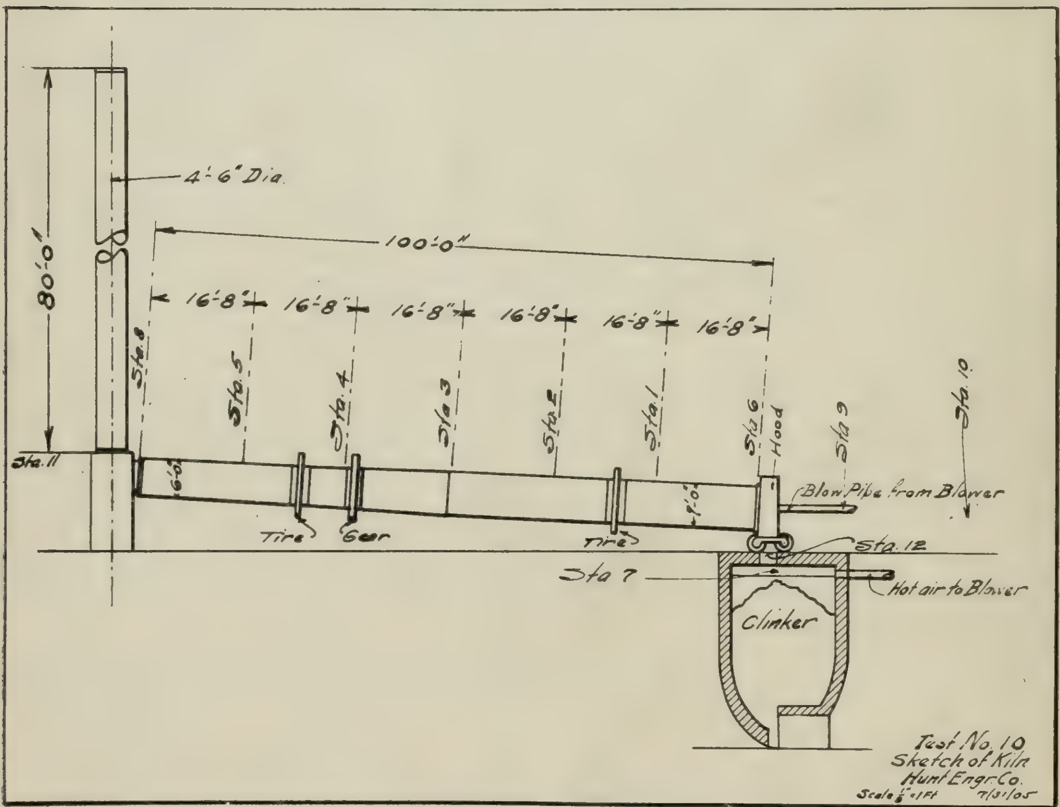
A 60 ft. by 6 ft. kiln, which was the standard up to two years ago, working on the dry process and under ideal conditions, will produce on an average 175 to 200 barrels per day, and at a fuel consumption of 130 pounds of coal per barrel of clinker burned. A 100 ft. kiln of 7 ft. diameter, working on the same material, will produce 225 to 250 barrels per day, with 100 pounds of coal per barrel. Of course different materials vary in their burning qualities and are affected considerably by weather conditions. These and many other conditions must be taken into consideration in comparing the results obtained with rotary kilns.

OBSERVATIONS ON THE OPERATION OF A ROTARY KILN.

The primary object of the following tests was to determine the value in point of cost of operation, fuel consumption per barrel, output per kiln, and in fact the value of the long kiln to the industry in general, and in particular, to the plant in question.

The tests were made August 31, 1905, by members of the engineering staff of the Hunt Engineering Company, of Iola, Kansas, who rebuilt the plant and installed the long kilns, utilizing the old vertical kilns for clinker pits and coolers.

In order to determine the actual temperature at various points




Sketch of 100-ft. Kiln.

throughout the length of the kiln, which to our knowledge had never been accomplished, several holes were drilled through the kiln shell and brick lining, as shown on sketch of kiln. A LeChatelier electrical pyrometer was used for determining the higher temperatures, 1° Fahrenheit being equivalent to 0.0001 volts.

Readings were taken at each station every 10 seconds where the heat was intense, and every 30 seconds where there was slight danger of melting the porcelain tube. The readings were noted so long as there was a marked rise in temperature, or when the curve became parallel to the Y-axis, and this rate of rise in temperature at the different parts of the kiln can be seen by referring to the curves Nos. 1 to 7 inclusive, while No. 8 is the curve of the maximum temperature observed.

The exact temperature at station 1 of 2496° F. is the temperature of the clinker itself and 2587° F. is the temperature of the gases.

When designing the plant, the length of the kiln was calculated so as to give a stack temperature of about 400° F. operating on the materials in question. This length was determined at 100 ft. and in actual practice and operation the waste gases had a temperature of 456° F.

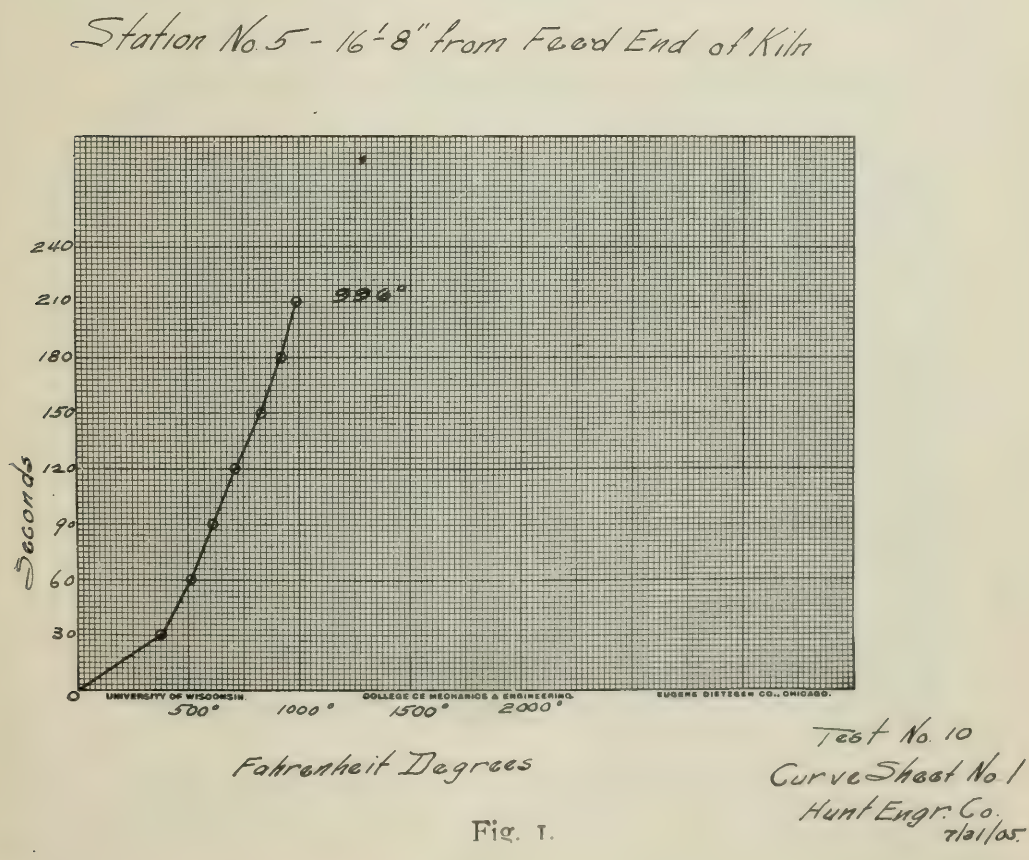



Fig. 1.

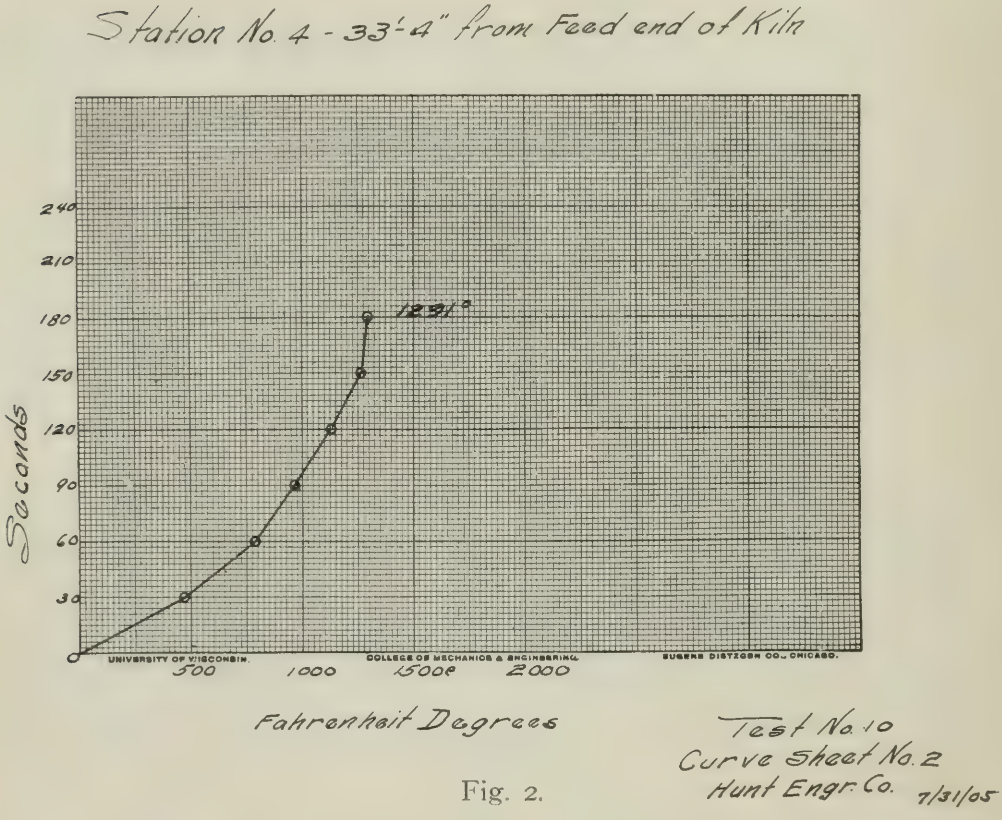

Station No. 4 - 33'-4" from Feed end of Kiln
Seconds
240
210
180
150
120
90
60
30
0
1291°
UNIVERSITY OF WISCONSIN.
COLLEGE OF MECHANICS & ENGINEERING.
EUGENE DIETZGEN CO., CHICAGO.
500
1000
1500°
2000
Fahrenheit Degrees
Test No. 10
Curve Sheet No. 2
Hunt Engr. Co. 7/31/05

Fig. 2.

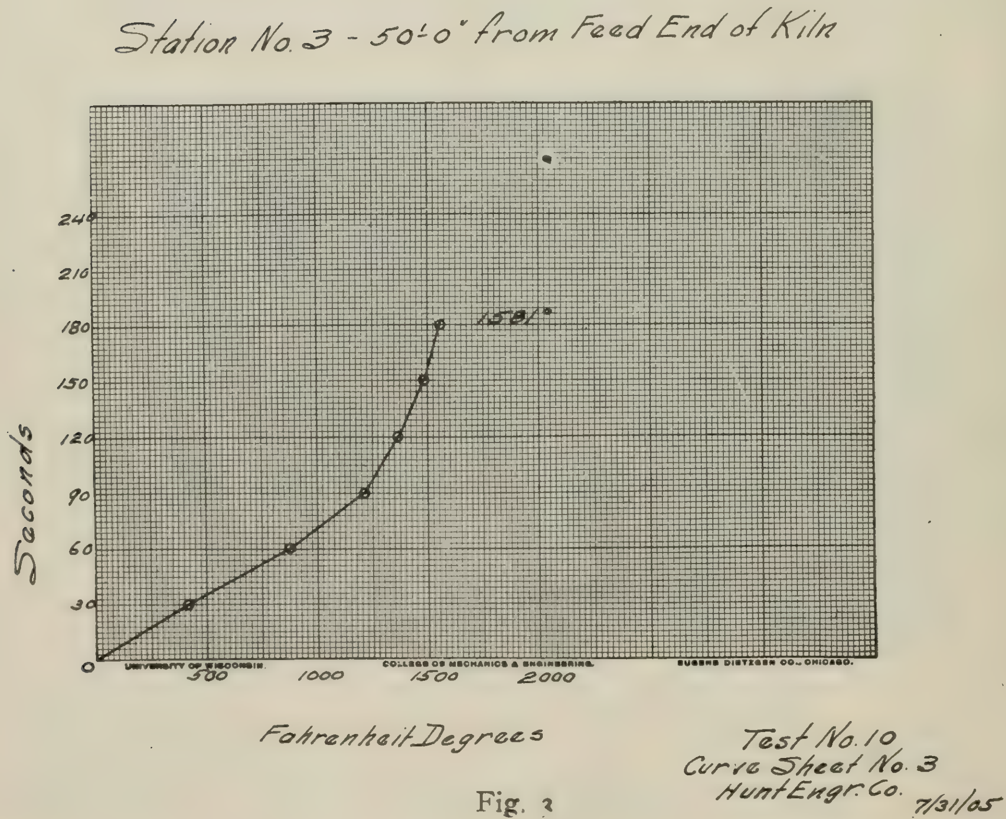

Station No. 3 - 50'-0" from Feed End of Kiln
Seconds
240
210
180
150
120
90
60
30
0
1581°
UNIVERSITY OF WISCONSIN.
COLLEGE OF MECHANICS & ENGINEERING.
EUGENE DIETZGEN CO., CHICAGO.
500
1000
1500
2000
Fahrenheit Degrees
Test No. 10
Curve Sheet No. 3
Hunt Engr. Co. 7/31/05

Fig. 3

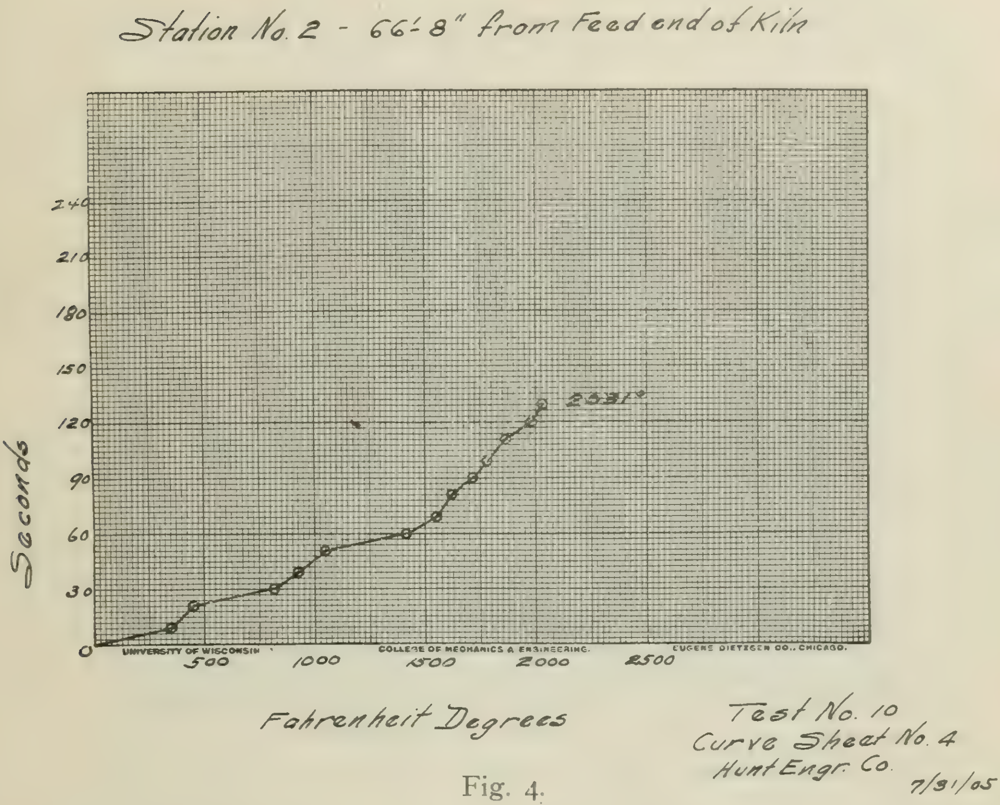

Station No. 2 - 66'-8" from Feed end of Kiln
Seconds
0
30
60
90
120
150
180
210
240
2331°
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
500
1000
1500
2000
2500
Fahrenheit Degrees
Test No. 10
Curve Sheet No. 4
Hunt Engr. Co.
7/31/05

Fig. 4.

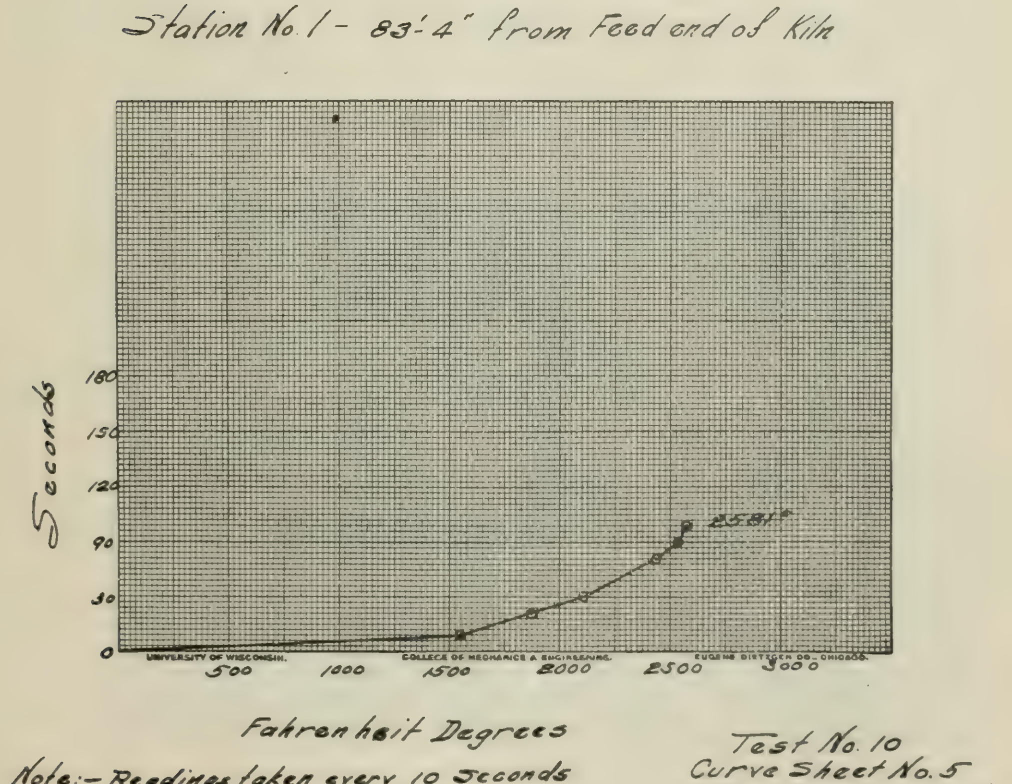
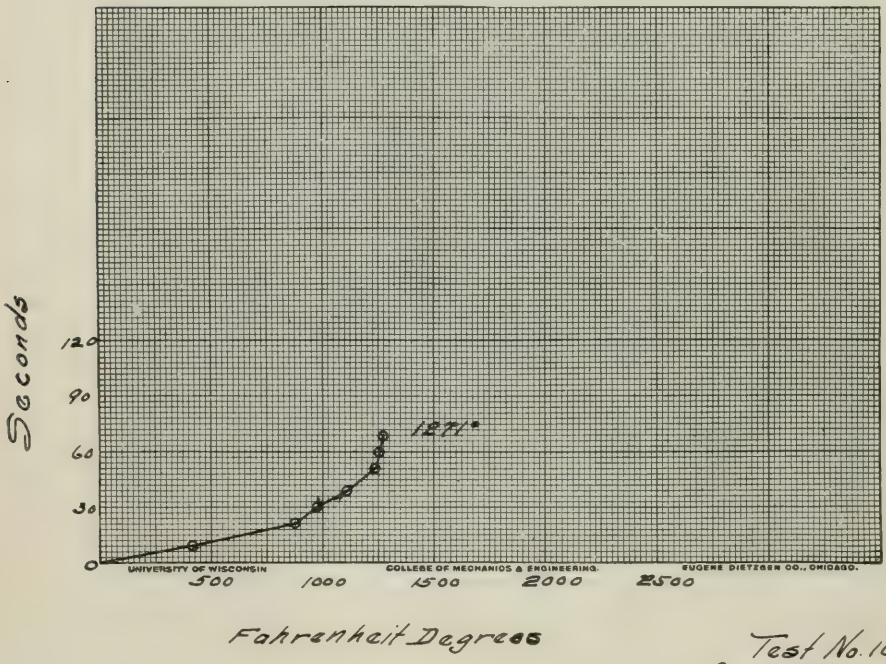

Station No. 1 - 83'-4" from Feed end of Kiln
Seconds
0
30
90
120
150
180
2581°
UNIVERSITY OF WISCONSIN.
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
500
1000
1500
2000
2500
3000
Fahrenheit Degrees
Note:- Readings taken every 10 seconds
Test No. 10
Curve Sheet No. 5
Hunt Engr. Co. 7/31/05

Fig. 5.

Station No. 6 - Thru Hood in Discharge end of [illegible]
(See Sketch)

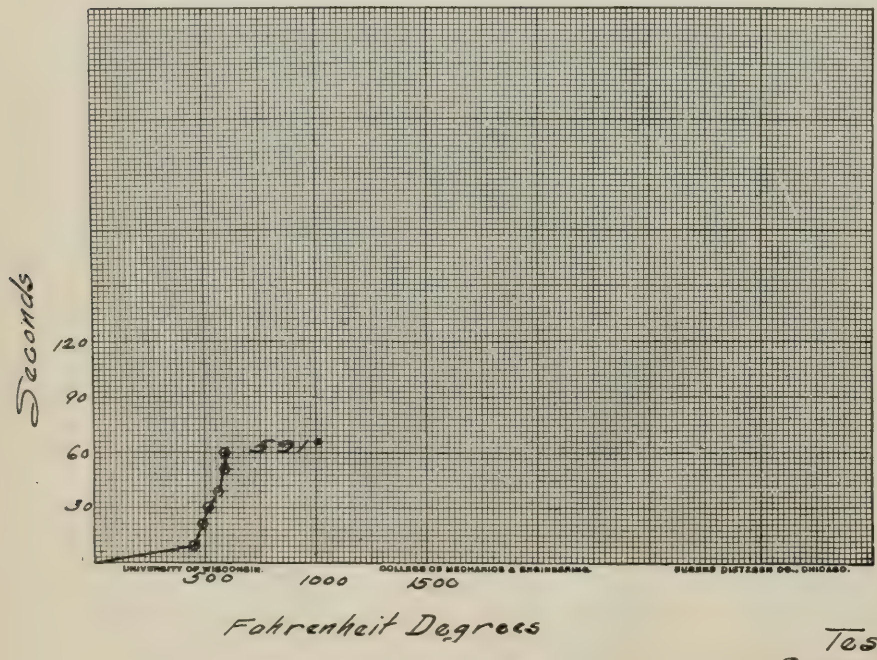



Note:- Readings every 10 Seconds

Test No. 10
Curve Sheet No. 6
Hunt Engr. Co. 7/31/05

Fig. 6.

Station No. 7 - 6" above Clinker pile in Clinker Pit




Test No. 10
Curve Sheet No. 7
Hunt Engr. Co. 7/31/05

Fig. 7.

Maximum Temperatures in 100' x 6' x 7' Rotary Kiln

Gases

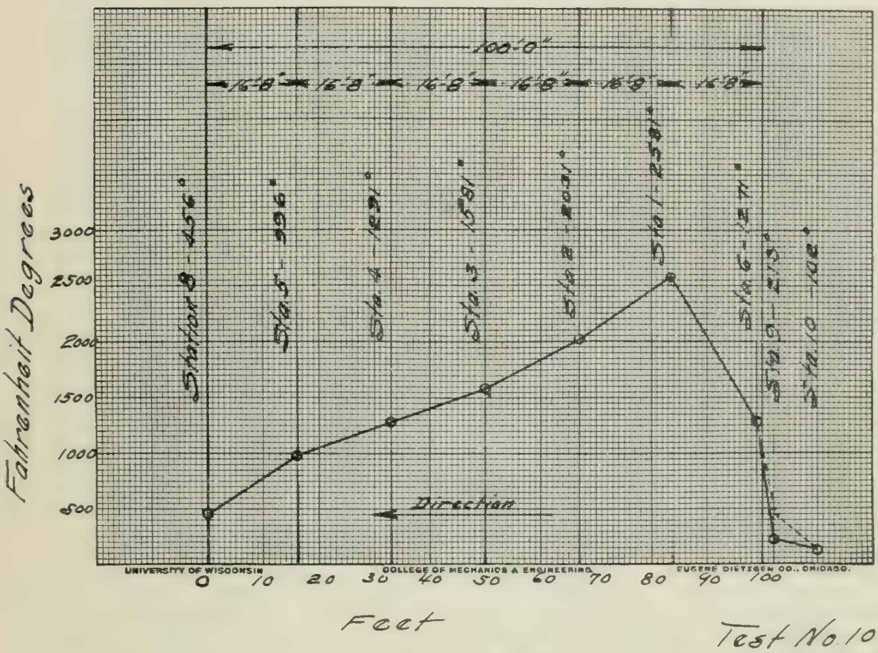
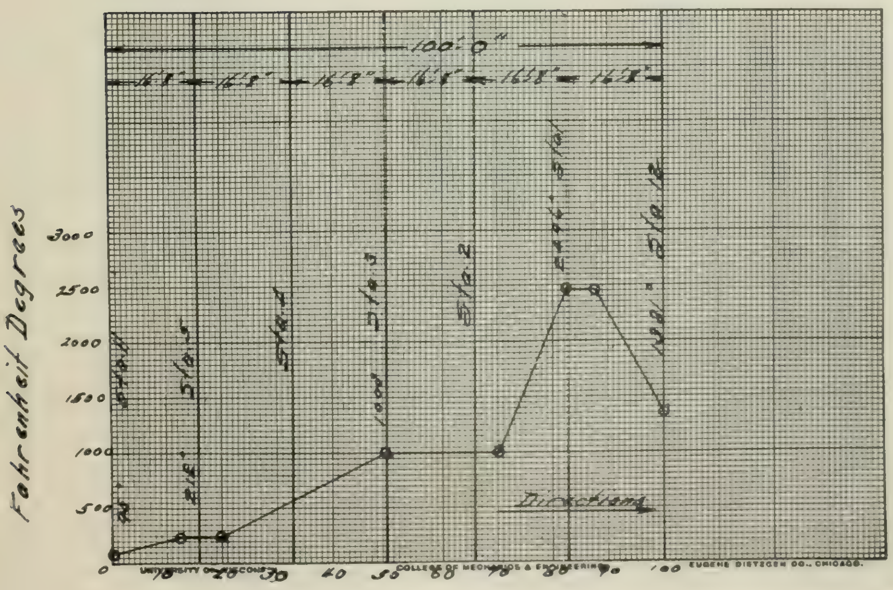



Fig. 8.

Test No. 10
Curve Sheet No. 8
Hunt Engr. Co 7/31/05

Maximum Temperatures in 100' x 6' x 7' Kiln

• Materials Calculated from Gas Temp.




Feet

Note:- Temperatures at Sta. 11, 1, 12 actually observed.

Test No 10
Curve Sheet No. 9
Hunt Engr. Co.

Fig. 9.

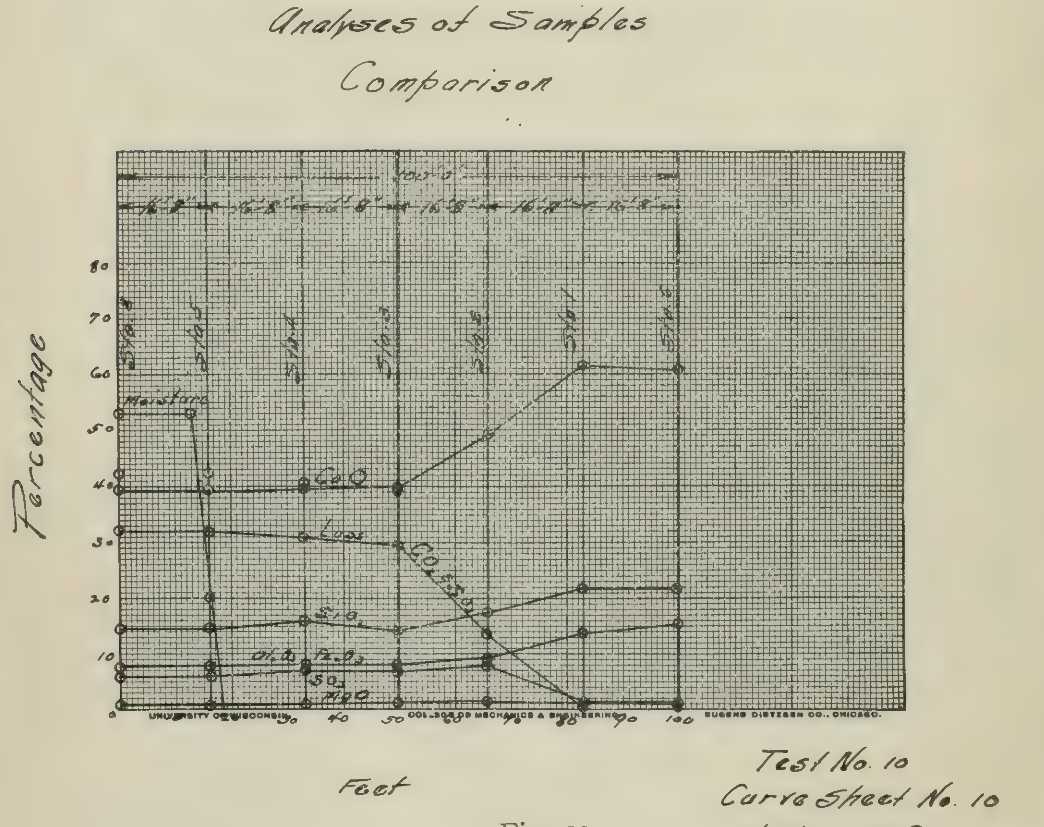

Analyses of Samples
Comparison
100'0"
16'8"
Percentage
Moisture
CaO
Loss
$CO_2$
$SiO_2$
$Al_2O_3$
$Fe_2O_3$
$SO_3$
MgO
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Feet
Test No. 10
Curve Sheet No. 10
Hunt Engr. Co.
7/31/05

Fig. 10.

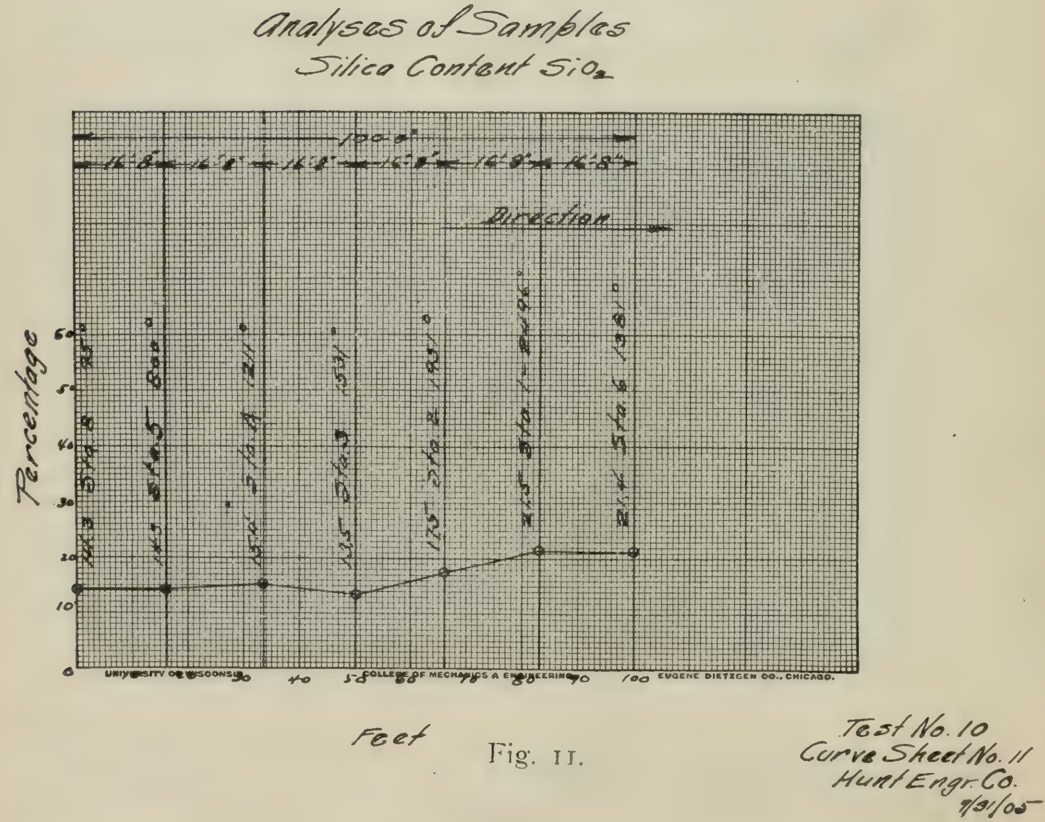

Analyses of Samples
Silica Content $SiO_2$
100'0"
16'8"
Direction
Percentage
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Feet
Test No. 10
Curve Sheet No. 11
Hunt Engr. Co.
7/31/05

Fig. 11.

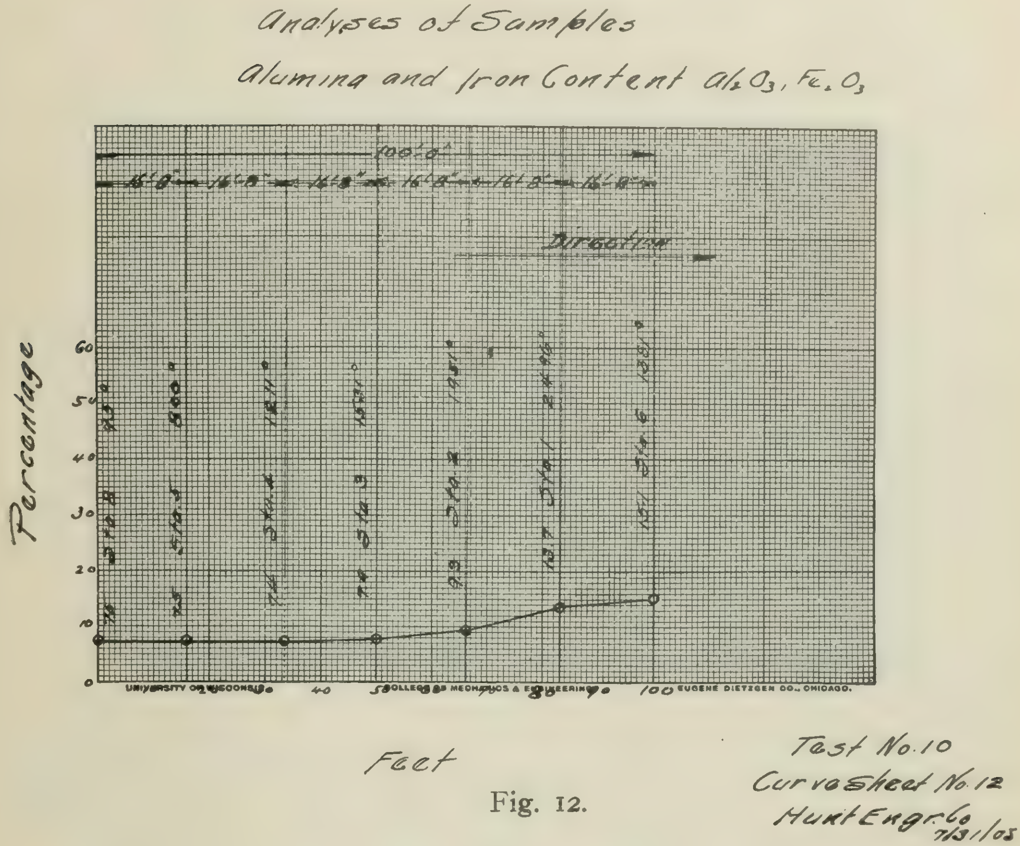

Analyses of Samples
Alumina and Iron Content $Al_2O_3$, $Fe_2O_3$
100'0"
Direction
Percentage
University of Wisconsin
College of Mechanics & Engineering
Eugene Dietzgen Co., Chicago.
Feet
Test No. 10
Curve Sheet No. 12
Hunt Engr. Co.
7/31/05

Fig. 12.

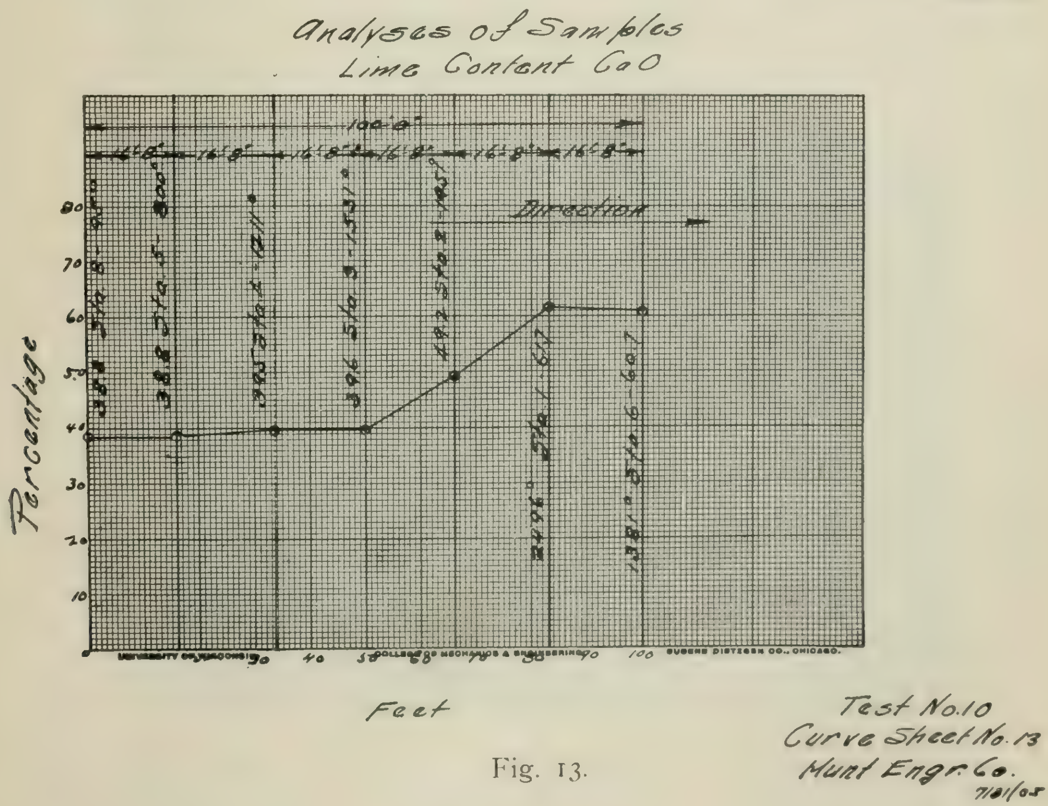

Analyses of Samples
Lime Content CaO
100'0"
Direction
Percentage
University of Wisconsin
College of Mechanics & Engineering
Eugene Dietzgen Co., Chicago.
Feet
Test No. 10
Curve Sheet No. 13
Hunt Engr. Co.
7/31/05

Fig. 13.

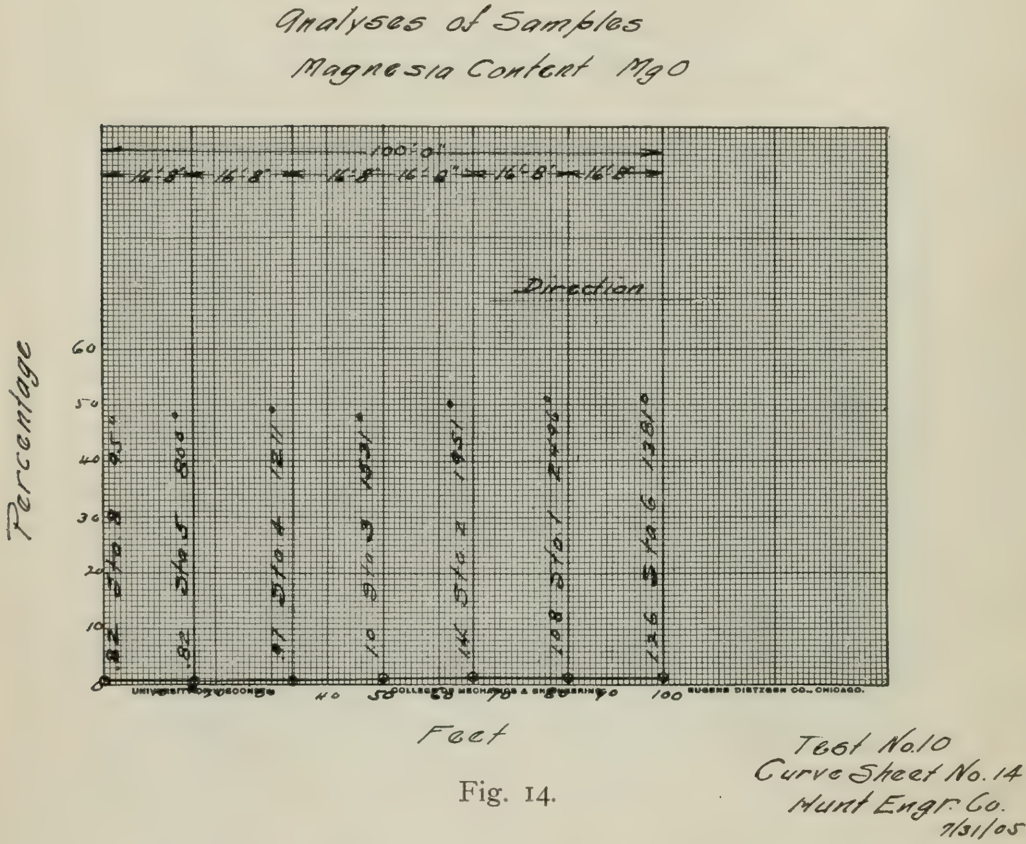

Analyses of Samples
Magnesia Content MgO
100'-0"
16'-8"
Direction
Percentage
60
50
40
30
20
10
0
40
50
70
80
100
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Feet
Test No.10
Curve Sheet No.14
Hunt Engr. Co.
7/31/05

Fig. 14.

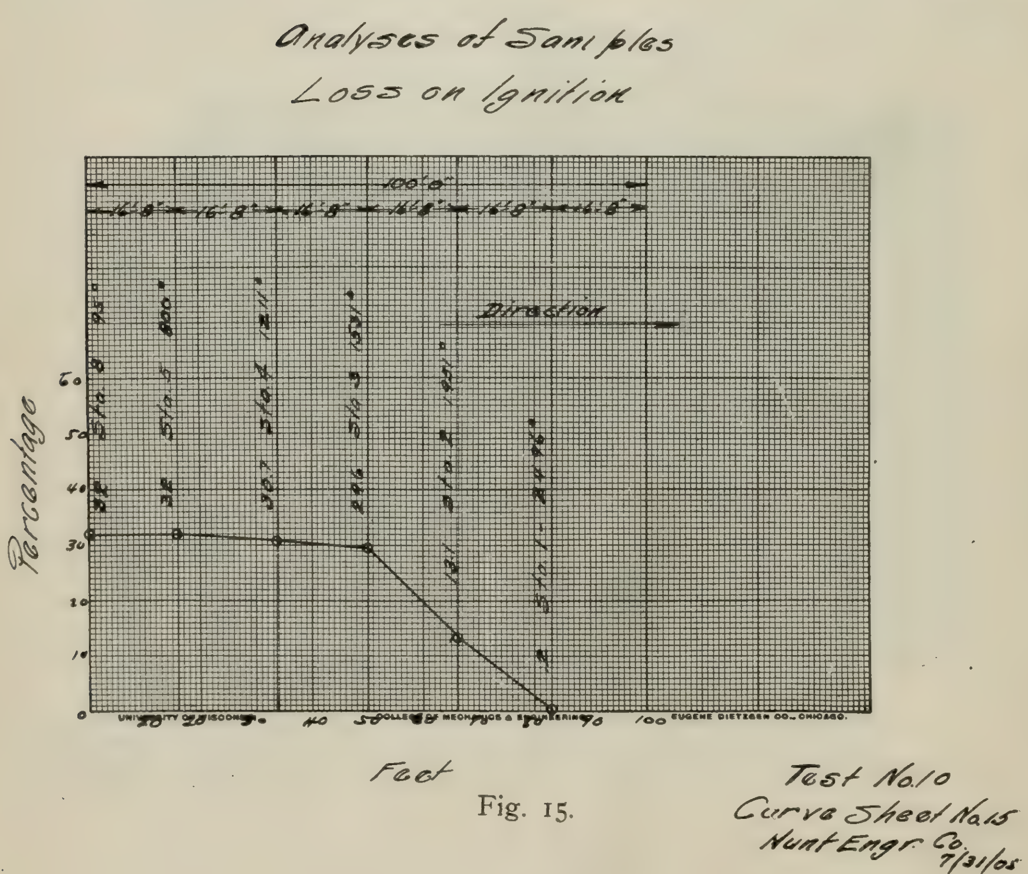

Analyses of Samples
Loss on Ignition
100'-0"
16'-8"
Direction
Percentage
60
50
40
30
20
10
0
40
50
90
100
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Feet
Test No.10
Curve Sheet No.15
Hunt Engr. Co.
7/31/05

Fig. 15.

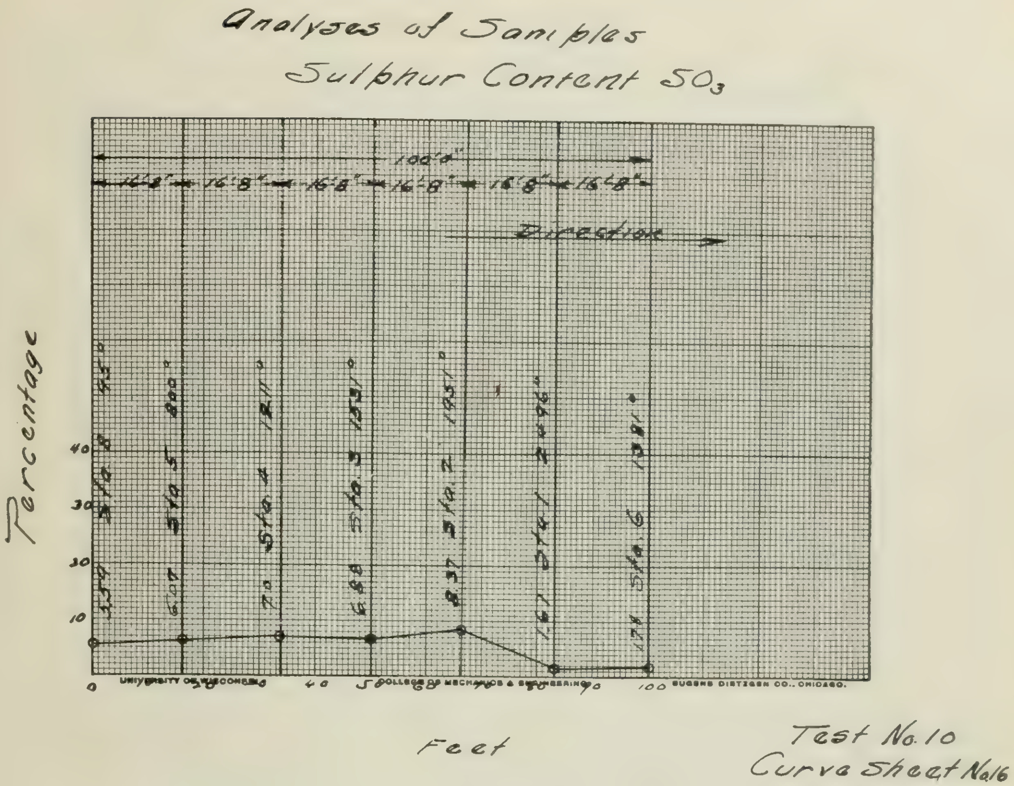

Analyses of Samples
Sulphur Content SO3
100'0"
16'8" 16'8" 16'8" 16'8" 16'8" 16'8"
Direction
Percentage
10
20
30
40
0
40
50
100
Feet
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Test No. 10
Curve Sheet No. 16
Hunt Engr. Co.
7/31/05

Fig. 16.

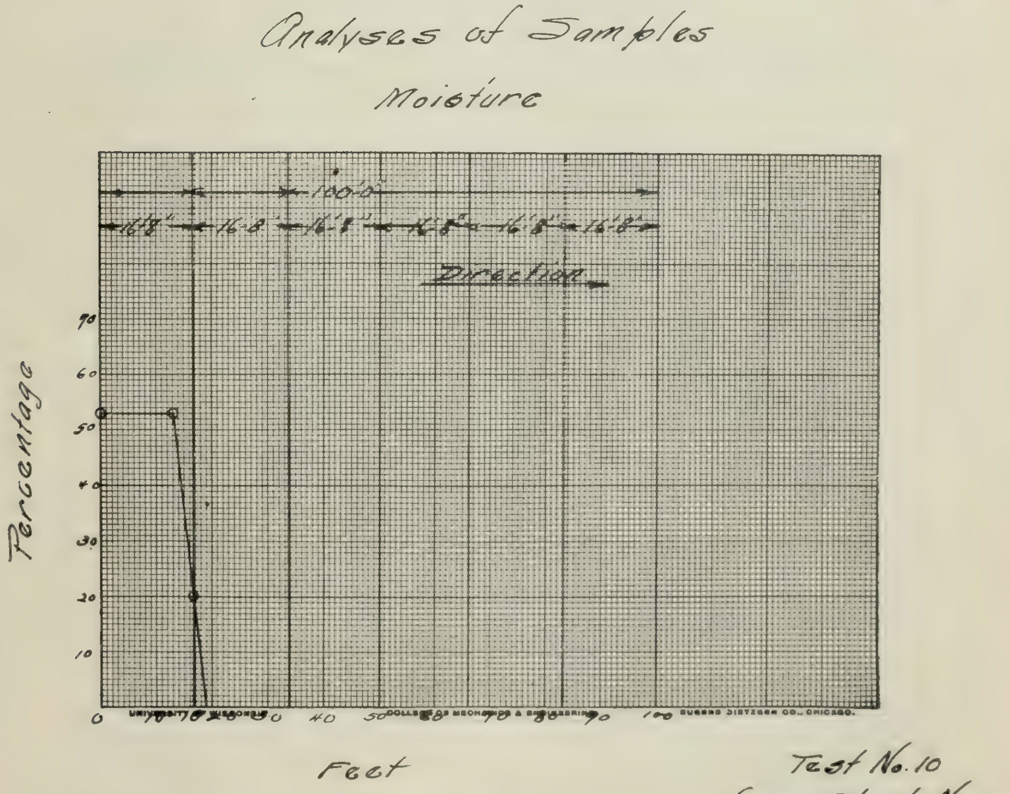

Analyses of Samples
Moisture
100'0"
16'8" 16'8" 16'8" 16'8" 16'8" 16'8"
Direction
Percentage
10
20
30
40
50
60
70
0
40
50
100
Feet
UNIVERSITY OF WISCONSIN
COLLEGE OF MECHANICS & ENGINEERING
EUGENE DIETZGEN CO., CHICAGO.
Test No. 10
Curve Sheet No. 17
Hunt Engr. Co.
7/31/05

Fig. 17.

## Conditions.

To produce one barrel of cement of 384 pounds, there is required 1319 pounds of slurry, containing 53 per cent. or 699 pounds of water, which has to be evaporated, leaving 620 pounds of dry mixture.

With an output of 166 barrels of cement per day of 24 hours, this is equal to 6.9 barrels per hour, and the time required to burn or clinker one barrel of cement is 0.145 of an hour. There is actually required 180 pounds of coal to burn one barrel of cement. The kiln is 100 ft. long and 6 ft. to 7 ft. in diameter as shown on sketch; is rotated at a speed of 1 revolution in 2 minutes, driven by a 15 H. P. motor. The stack is 4 ft. 6 in. in diameter by 80 ft. high.

The proximate analysis of the Iowa coal is:

| | |
|---|---|
| Volatile matter | 43.30% |
| Fixed carbon | 30.98% |
| Ash | 19.56% |
| Sulphur | 6.56% |

By calculation from this analysis the heat value of this coal is taken at 10094 B. T. U.

Analysis of the cement material:

### Raw Mixture.

| | |
|---|---|
| $CaCO_3$ | 74.46% |
| CaO (calculated) | 41.36% |
| Insoluble | 19.50% |
| Sulphur | 6.00% |
| Ignition loss | 33.14% |

### Cement.

| | |
|---|---|
| CaO | 64.75% |
| $SiO_2$ | 19.75% |
| $Fe_2O_3$ | 6.25% |
| $Al_2O_3$ | 6.50% |
| Mg. O | .89% |
| $SO_3$ | 1.90% |

### Temperatures Observed.

| | |
|---|---|
| Air entering kiln from blower | 213° F. |
| Air surrounding the kiln | 102° F. |
| Slurry | 95° F. |
| Average of the kiln shell | 260° F. |
| Clinker, falling from the hood | 1381° F. |
| Waste gases entering the stack | 456° F. |
| Clinkering zone | 2496° F. |

DISTRIBUTION OF HEAT PER BARREL OF CEMENT

1. Evaporation and heating of 699 pounds of water to 456° F. waste gases temperature...838,883 B. T. U.
2. In the dry mixture, of 620 pounds, with 461.7 pounds $CaO_3$ to be decomposed..........353,200 B. T. U.
3. With 37.2 pounds $SO_3$ to be liberated........ 70,306 B. T.U.
4. With 620 pounds dry mixture, heated from 95° F. to 1000° F. ($CO_2$ reduced)...........112,220 B. T. U.
5. With 384 pounds of clinker heated from 1000° F. to 2496° F. ........................147,856 B. T. U.
6. With 384 pounds of clinker discharged at 1361° F. into the air at 213° F. the loss is........107,835 B. T. U.
7. Loss by radiation from 2042 square feet surface of kiln and 66 square feet of hood, reduced to the unit of one barrel of cement, equals..201,256 B. T. U.
8. Heating up of air blown into the furnace with a pressure of 5.75 inches of water and with 3 in. diameter of nozzle, amounting to 3878.5 cu. ft. of air per barrel of cement burned. amounts to ........................... 6,040 B. T. U.
   The combustion of Iowa coal (analysis given) requires about 8 pounds of air per pound of coal (theoretical), and allowing 50 per cent. excess of air, the consumption of 180 pounds of coal per barrel of cement requires 2160 pounds of air.
9. Loss of heat by the waste gases at a temperature of 456° F. and of 2160 pounds of air heated from 102° F. amounts to ................175,824 B. T .U.

With the old kiln of 60 ft. length the waste of heat by higher temperature of waste gases (item 9), greater loss of heat in the clinker (item 6) and greater loss in evaporation and heating of the water (item 1) amounts to a saving, with the 100 ft. kiln, of 483,126 B. T. U., which is equivalent, under ordinary operating conditions, to about 48 pounds of coal per barrel of cement.

Further improvements can be effected by having the slurry of a temperature of 200° F. (item 1),—a saving of 73,194 B. T. U.; by using the air of a temperature of 450° F. (item 6),—a saving of 22011 B. T. U.; by the saving of a moderate stack temperature (item 9), 123,120 B. T. U.

The total saving, with these improvements, using the 100 ft. kiln shown, as against the old 60 ft. kiln, amounts to 701,451 B. T. U. equivalent to about 72 pounds of coal, operating under ordinary conditions.

HEAT SUPPLIED THE KILN PER BARREL OF CEMENT.

10. Heat produced by chemical reactions; from the lime (CaO) and magnesia (Mg O); from 248.64 pounds CaO per barrel of clinkers there is liberated 237,164 B. T. U.; from 3.4 pounds MgO per barrel of clinker there is liberated 5061 B. T. U., a total by chemical reaction of .................... 242,225 B. T. U.

11. From the air entering the kiln through coal feeder blow pipe ...................... 6,040 B. T. U.

12. From the gases ($CO_2$ and $SO_2$) reduced from 1000° F. to 456° F. there are ........... 26,625 B. T. U.

13. Heat from the combustion of 180 pounds of the Iowa coal, of a thermic value of 10094 B. T. U. on the assumption that 1.5 times the theoretical quantity of air is supplied for combustion, the heat used amounts to, per barrel of cement ...................... 1,755,720 B. T. U.

The total of these four items is.............. 2,030,610 B. T. U.

## RECAPITULATION.

DISTRIBUTION OF HEAT IN KILN PER BARREL OF CEMENT.

| | | |
|---|---|---|
| 1. | Evaporation of water .................... | 838,883 B. T. U. |
| 2. | Carbonate of lime, decomposed .......... | 353,200 B. T. U. |
| 3. | Sulphuric anhydride liberated ............ | 70,308 B. T. U. |
| 4. | Dry mixture heated to 1000° F............. | 112,220 B. T. U. |
| 5. | Clinker heated to 2496° F................. | 147,856 B. T. U. |
| 6. | Clinker discharged at 1391° F............ | 107,835 B. T. U. |
| 7. | Radiation losses, kiln and hood........... | 201,256 B. T. U. |
| 9. | Heat loss in waste gases .................. | 175,824 B. T. U. |
| | Total of these items .................. | 2,007,382 B. T. U. |

But the total heat, per barrel of cement supplied the kiln, items 10, 11, 12 and 13 is............. 2,030,610 B. T. U.
and the difference unaccounted for is.......... 23,228 B. T. U.

If Fairmount coal from West Virginia be used, with a proximate analysis of

| | |
|---|---|
| Fixed Carbon ............................ | 53.24% |
| Volatile ................................... | 38.10% |
| Ash ......................................... | 8.06% |
| Sulphur ................................... | .75% |

the thermic value, based on this analysis, is 12411 B. T. U.

The amount of this coal required to burn one barrel of cement is 146 pounds.

The Iowa coal has ash, of 19.16%, with about the following composition,—$SiO_2$—5%, $Fe_2\ O_3$—10%, and $Al_2\ O_3$—4%, which accounts for the higher percentage of silica, iron and alumina in the finished produt than would occur if a coal was used with a lower content of ash.

## OPINION.

Assuming that certain further improvements and alterations be effected as recommended, then a further saving of 218.325 B. T. U., in the present installation, can be made equivalent to 22 pounds of the "Iowa Slack" coal, which will reduce the coal consumption per barrel to 158 pounds. For the sake of comparison, if Fairmount (West Virginia) coal be considered, then this reduction would be equivalent to 18 pounds, or 128 pounds of coal per barrel of cement burned; this is believed to be as low as it can be reduced without the installation of complicated and costly apparatus, whose utility and practicability are still to be demonstrated.

The stack gases are as low in temperature as is consistent for good draft without mechanical means. To prove the results actually obtained are as satisfactory in point of economy and cost as could be obtained through the use of the system as installed by Prof. Carpenter at Cayuga Lake (which consisted of passing the waste gases from a 60 ft. kiln to the grates of boilers, and thus conserving the heat, otherwise wasted, for power purposes) the following calculations are given:

From the curve sheet No. 8 estimate approximately the temperature of a 60 ft. kiln, operating under similar conditions to those in this test. At 50 ft. (station 3) the gases in the kiln are at 1581° F. and at station 4, 66 ft. 8 in. from the furnace end of the kiln, they are 1291° F., so it may be assumed that at 60 ft. the temperature is 1400° F.

However in a 60 ft. kiln, operating on the wet process, these gases are seldom above 1000° to 1200° F., and assuming them at 1000° F. to conform to the foregoing calculations, the 100 ft. kiln effects at the present time a saving over the 60 ft. kiln of 50 pounds of coal per barrel of cement.

Then with waste gases at 1000° F. they will carry under the boiler the following heat units: In the case of the coal in question, 2160 pounds of air are required to burn one barrel of cement, and the waste gases hold 446,040 B. T. U.

Assuming a boiler efficiency of 70 per cent., then these 446,040 B. T. U. become 312,228 B. T. U. actually converted into steam for power purposes, which is equivalent to 32 pounds of coal saved per barrel of cement, by utilizing the stack gases from a 60 ft. kiln operating on the "wet process."

Then the long kiln, besides being a much simpler installation and less costly, has an advantage of 18 pounds of coal per barrel of clinker burned. The long kiln will be in practically continuous operation, while in the case of the waste-gas boiler installation, the one must necessarily depend, to a certain extent, upon the other, in their operation.

## Analysis of Samples.

If a study is made of comparison of action throughout the length of the kiln, of curve sheet No. 10, it will be noticed for the first 50 ft. there is comparatively no change in the sulphur, silica, magnesia, alumina and iron contents. The moisture is driven off so that at station No. 5 the material was practically bone dry. The $CO_2$ began to be driven off between station 5 and 4, slowly, but starting at the middle of the kiln (station 3) it dropped rapidly for the next 33 ft. In plotting the curve of maximum temperatures of materials, curve sheet No. 9, it is assumed that the $CO_2$ is driven off where the temperature of the material is 1000° F. as the temperature of the gases at this point (station 3) is 1500° F. and beginning at this point, referring to the comparison curves of analysis, the $CO_2$ is rapidly driven off, but the $SO_3$ is driven off between stations 2 and 1.

Then the probable action in the materials is this; the material is heated from its entering temperature to 212° F. where the water is converted into steam, and during this process, the temperature remains constant;—then the temperature rises gradually to 1000° F., where the $CO_2$ is given off and the temperature again remaining constant, but rises rapidly after this action to the clinkering temperature of 2496° F. Here the temperature probably remains constant a short time, and then decreases rapidly as the cooler entering gases strike it.

The temperature of the gases as plotted on curve sheet No. 8 is accurate within the limits of the pyrometer. A point worth mentioning is that in reconstructing this plant use was made of the old vertical kilns for clinker pits, as shown in sketch of kiln. The plant before reconstructing was not a paying proposition financially, because of the high cost of coke (from $8.00 to $11.00 per ton), and cost of labor due to the old methods employed. But by the installation of the long kiln, the use of Iowa slack coal at a cost of $2.60 per ton and containing a high percentage of ash and sulphur, can be used. The sulphur in the raw mixtures, as will be noticed from the curve, is about 7 per cent. and is reduced to 1.78 per cent. in the clinker. The manufacturing cost per barrel has been reduced to one-half the original amount.

COPY OF TESTS MADE OF THE CEMENT BY UNITED STATES EXPERT.

Bin 10.

Setting, initial 2½ to 3½ hours. Specific gravity 3.20.
Setting, final 8 to 9 hours.
Fineness, Number 100 screen, 95.6%.
Boiling test for soundness, O. K.
Tensile strength tests—neat.
1 day 338 pounds.
7 days 573 pounds.
28 days 665 pounds.
Tensile strength tests 1-3 sand mortar.
7 days 266 pounds.
28 days 369 pounds.

DISCUSSION.

*A Visitor*—I would like to ask for a little information in regard to the object of the bottle neck kiln; at what point is that change in diameter made?

*Mr. Soper*—The change varies. In a 60-ft. kiln that will probably be 20, 20, 20, and long taper. In this instance, because of the greater diameter, there are more gases at the stack end, and whether you are choking those gases down by having the same diameter (pointing to sketch), or else giving more space here (pointing to sketch), and whether that makes a difference in the output, I do not know. In actual practice, operating side by side, the straight kiln produces about 20 per cent. more material.

*Mr. Bergquist (M. W. S. E.)*—The cases referred to are the wet process, I suppose?

*Mr. Soper*—The semi-wet. In the dry process, the last kiln I saw was 80 feet long.

*Mr. Bergquist*—Our experience has been quite the reverse with the straight and tapered kiln. We use the dry process in two different kilns; at one plant 60-ft. kilns, straight, and at another 80-ft. tapered kilns are used. The 60-ft. kiln gives an output of about 10 barrels per hour, while the output of the 80-ft. tapered kiln is 14 barrels per hour, which is out of proportion to the length of the kiln.

*Mr. Soper*—How much?

*Mr. Bergquist*—It should be 10.5 barrels in the 60-ft. kiln, at the rate of 14 barrels per hour for the 80-ft., while it is only 10 for for the 60-ft. I think, in the case of the wet process, you have possibly an advantage of area in a straight kiln, which would increase the exposure of the material for drying purposes.

I would like to make a suggestion in regard to your classification of processes. Referring to the corrections you mentioned, under "Miscellaneous," in the case where slag and limestone are ground together and burned to a clinker, it would come under the "dry process;" and possibly the by-products from manufacture of soda-

ash mixed with clay would also come under one of those processes above which would cut out that fourth class entirely.

*Mr. Soper*—The only reason for making a "miscellaneous" division was that there are only a few plants using slag.

*Mr. Bergquist*—Speaking of processes,—I am not aware of any other than the "Dry," "Semi-dry," and "Wet." Where blast furnace slag and limestone are used for raw material, as is the case at the plants of the Illinois Steel Co., the process is identically the same as where the cement rock is used, in the Lehigh Valley regions.

There is another point which is not quite clear to me,—in this semi-wet process you speak of the necessity of grinding to 88 per cent. only, while in the dry process it is necessary to grind finer. Why should it be necessary to grind finer in the one case than in the other?

*Mr. Soper*—We will concede that a Lehigh limestone, which is already mixed pretty nearly perfect by nature, has been more thoroughly mixed than man could do it. In two independent materials, if you grind to 88 or 90 per cent. mixed with water, you get an absolutely uniform mixture as it is being agitated all the time; with two independent materials, as a dry powder, unless ground finer you will have those little chunks of vastly different materials. We tried, on one or two kilns, a test lasting about a month; the resulting clinker was not uniform in quality. There are a great many plants operating by the dry process on independent materials, which are turning out good cement and which have also turned out *bad* cement.

*Mr. Bergquist*—Our material is already not only mixed but largely combined with lime, and therefore the percentage of the two materials is about the same; but it seems to me even if you have limestone and shale, and wet it, then put it into the kiln and it travels, say, 20 feet (I believe, according to the sketch), when it is dried, then you have it again in powder. Why is it not necessary for those particles to be just as fine as if in powder 20 or 30 feet up in the kiln?

*Mr. Soper*—I cannot explain that. However, I know actually that the two plants operating on independent material and using the semi-wet system have never had one barrel rejected. I can cite two or three plants operating on the dry process and of independent materials, which have been barred from the market as not up to uniform quality. This might have been due to poor operation, however.

*Mr. Bergquist*—Most likely. If ground together first and passed through a tube mill it should be thoroughly mixed, and I do not believe you will find streaks in it, not even under a microscope.

Another thing I would like to ask about. Referring to Fig. 9, the line showing the rise in temperature,—when you come up to 212° it is stationary for some time; approximately 20 feet from the end it begins to rise again. That is correct, I believe. That would mean that the material is dry at that point; in other words,

a 100-ft. kiln for this wet process should be equivalent to about an 80-ft. kiln for dry process?

*Mr. Soper*—Yes.

*Mr. Bergquist*—Comparing the temperature at these various points it would indicate that the gas temperature 20 feet from the discharge end would be about equivalent to the gases of a dry process kiln.

*Mr. Soper*—Yes, that would be something over 2,500. Do you mean at 80 feet?

*Mr. Bergquist*—Yes. In other words, at the point where the material is dry it is about 1,100, that is also equivalent to the actual observation in the dry process kiln. Consequently you should also have the capacity of the 80-ft. dry process kiln.

*Mr. Soper*—Not with these materials.

*Mr. Bergquist*—If these materials were dried?

*Mr. Soper*—Yes. But you are comparing these with your own observations on an 80-ft. dry process kiln.

*Mr. Bergquist*—Our material may be clinkered at a different temperature. I have made some observations of temperature in our own kilns.

*Mr. Soper*—What is the temperature of your waste gas?

*Mr. Bergquist*—Approximately 1,000°.

*Mr. Soper*—The temperature of the discharged clinker?

*Mr. Bergquist*—The discharge from the kiln, I should think was approximately what is shown here; it would be a bright red heat.

*Mr. Soper*—That sketch shows two more stations; one is the temperature of the clinker coming out of the clinker cooler down at the bottom, and the other is 10 feet from the kiln; i. e., the temperature of the atmosphere—102°.

*Mr. Bergquist*—Referring to the maximum temperature of the kiln, I have tried to make some observations with a French pyrometer called the "Lunette." It is approximate, but it seems near the fusing point, to be about 2,600.

*Mr Soper*—That might be, in between those last two points shown, it might run on up a little. That is very possible.

One point I wanted to bring up,—if any of the members are considering building cement plants, the point of locating the plant and the studying of all the different requirements, is an important one. Our company has been looking, since April of this year, for a location for a company, and our representatives have probably spent at least four or five days a week in actual search for an ideal proposition—one that would possess all these requirements; we have followed out-croppings of a certain limestone for several hundred miles, and where we would find an out-crop of limestone there would be no shale near; or another place where these two would be found together we would not find good fuel, and if we found fuel the titles of the land might be vague, etc. We finally succeeded in getting a location where all these points seemed fulfilled, and it cost, approximately, $8,000 to locate that proposition, that expense

being made up of analyses, railroad fares, and for laborers digging samples, blasting, etc.

*Mr Warder*—(M. W. S. E.)—Was that just the preliminary work?

*Mr. Soper*—Yes, and locating the proposition. The point is in saving this waste heat from the kilns. In locating a plant, what is the use of putting a Portland cement plant in a district where fuel is $2.00 to $3.00 a ton, and then putting in a lot of complicated machinery to save a few hundred dollars, when you can locate under better conditions where fuel is less than $1.00, thus making you a saving.

*Mr. Bergquist*—Do you have any trouble with stack draft?

*Mr. Soper*—As a rule a stack is so hot you cannot hold your hand on it, but this one is only just warm.

*Mr. Bergquist*—You had, all the time, sufficient stack draft?

*Mr. Soper*—We had so much draft that we had to keep the damper partly closed.

*Mr. Carter*—(M. W. S. E.)—What was the height of the stack?

*Mr. Soper*—It was 80 feet high. Here is another point about the stacks. There were four kilns in that installation, with two steel stacks, and one old brick stack which was utilized, that belonged to the original plant; it was about 80 feet high, the walls were very thick; it was used in the place of two steel stacks. In variable weather the burners have no trouble at all with the brick stack, but in the steel stacks, the blaze goes up and down; this shows the difference in the two stacks.

*Mr. Bergquist*—You had trouble, then, with the draft in the steel stack. What was the diameter of the brick stack?

*Mr. Soper*—Six feet.

*Mr. Bergquist*—That probably accounts for the better draft there. Did you have any arrangement for regulating the draft where the two kilns went into one brick stack?

*Mr. Soper*—Yes, where it connected into the brickwork there is a gooseneck with a damper.

*Mr. Bergquist*—In these figures what have you considered the coefficient for the thermal capacity of the clinker?

*Mr. Soper*—That data was compiled, but it was left out of this advance paper. I found five authorities and averaged them up. The figures varied somewhat. The heats of liberation also varied a great deal.

*Mr. Warder*—Wherein does the cement rock of Louisville differ from the argillaceous rock of the Lehigh district?

*Mr. Soper*—Those Louisville cements are natural cements.

*Mr. Warder*—Is not that an argillaceous cement rock?

*Mr. Bergquist*—It is much higher in silica and also it is too high in magnesia for a Portland cement.

*Mr. Soper*—A true Portland cement contains 2½ per cent to 5 per cent. magnesia; if it contains anything above that, the cement is condemned. The Louisville hydraulic cement and Milwaukee

cement contains a higher percentage of magnesia. I have samples of cement taken at Milwaukee which contain from 25 to 35 per cent of magnesia.

There is a plant being promoted at the present time which I think will be built in the state of Louisiana, where oyster shells and clay are to be used. The shells are there now, piled up on the banks, and are dug with a clam shell dredge; they also have a contract with the canning factories to furnish shells at a reasonable price.

*Mr. Bergquist*—What is the extent of the raw material?

*Mr. Soper*—It is claimed it will last for 50 years.

*Mr. Seafert*—The location is near New Orleans, is it not?

*Mr. Soper*—Yes. A man in Michigan located a mammoth plant on the water, so the big boats could take the output. They had a nice shale deposit about seven miles away and mined their own coal. They had a large deposit of marl 50 miles away. Short dryers were installed 30 feet long—four of them, to dry the marl so it could be hauled in cars. They used direct heat to dry this marl. Those dryers would perhaps dry a carload in a day, or every other day, for a 1,000-barrel plant. They had to bring this dry marl down to the plant and haul the shale also, just for the sake of being on the water front. The first thing, they found the dryers were too short and would burn out, as they were not adapted to the intense heat necessary to get out the water. They then put in rotary kilns, 60 feet long—five of them. They afterwards put in a big pumping plant with agitators. There was a vacuum pump on the boat, the pumping being done by steam. Those five dryers maybe kept two kilns going. The plant I am referring to is in Bay City.

*A Visitor*—How do you determine whether you have a material that will make a good cement?

*Mr. Soper*—It first has to be analyzed. In driving across the fields looking for material, it is noticed that a certain species of bushes grow on or near the limestone outcrop. They do not grow anywhere else, and where there are those bushes, you know there is limestone. You first endeavor to determine the extent of that material, for unless there are at least 100 acres of it, it would not pay to build a plant, because one plant will use up an acre of limestone a year. If the supply seems to be all right, then you get some laborers and take hand drills and drill down to the rock, getting clean samples down underneath the surface. Those samples are analyzed, and if satisfactory, then you look for the shale, and also investigate the fuel question. The limestone is of the first importance as it forms the greater part of the raw material.

*Mr. Seafert*—Can cement be made as cheap in the east when using coal for fuel, as by using gas in Kansas?

*Mr. Soper*—As near as I can find out the cost in the east is 60 cents per barrel; of that, the fuel probably represents 18 cents.

*Mr. Bergquist*—In that price of 18 cents per barrel for fuel, do you include the power also?

*Mr. Soper*—Yes. Fuel for power and burning.

*Mr. Warder*—Is there any opportunity for cement plants in the Indian Territory? Do you know anything about the natural material there?

*Mr. Soper*—We have been over pretty nearly every foot of ground in the Indian Territory, and there are several good locations. There are none where the gravity system could be used. There are a great many places where shale and limestone are found together, but gas matters are in quite a tangled shape, and the Government will not allow any transfer of property at present. There is a very good field there, however.

*A Visitor*—Does that estimate of 60 cents include depreciation?

*Mr. Soper*—No, that varies. The 60 cents includes the actual mill cost. I know of a plant near the Lehigh district, operating on dry process, and they cannot make the cost less than 70 cents.

*Mr. Bergquist*—Is there much limestone in the state of Michigan?

*Mr. Soper*—No, not much. There is some at Traverse City and Alpena.

*Mr. Seifert*—Does that Traverse City plant get its limestone from Ohio?

*Mr. Soper*—No; I understand some plants get their shale from Ohio but not their limestone. There are several good limestone deposits around Traverse City. In Wisconsin there is a good deal of limestone but it is too high in magnesia.

## THE PRIME MOVER OF THE FUTURE.

C. E. Sargent, M. W. S. E.

*Presented Dec. 6, 1905.*

The economy of the internal combustion engine has been recognized from its inception. Both the theoretical and practical efficiency of this type of prime mover is from two to five times greater than that of the average externally fired heat engine. The smallest gas engines have a thermal efficiency from 20 to 24 per cent, while the largest steam engine, with all modern refinements known to the art, does remarkably well to turn into work 12 per cent of the heat supplied to the furnace under normal conditions. For well known reasons the thermal efficiency of steam engines increases with the cylinder volume, but although this increased efficiency is not so apparent in internal combustion engines, a comparison of the thermal efficiency of an ordinary gas engine with the largest and most economical engine propelled by steam, while perfectly fair to both types, still shows 100 per cent in favor of the internally fired prime mover.

A plant recently tested by the writer in which producer gas from anthracite culm was used, showed the cost of fuel per horse power hour to be about 1.5 mills. By selling the by-products of the bituminous gas producers at the market price, a recent writer in "Power" claims that power from gas engines can be generated 14 per cent cheaper than from water falls.

As the efficiency of the steam plant depends largely on the rapid transmission of heat through boiler walls, and the efficiency of the gas engine on our ability to prevent heat from passing through, the gas engine cylinder can be very much thicker and stronger than the boiler shell, and while the pressure during rapid combustion exceeds the pressure usually carried in the steam boiler, accidents from exploding cylinders are almost unknown, and accidental gas explosions doing considerable damage, very rare.

The first cost of a large gas engine plant, including producers, coal handling apparatus, piping, scrubbers, cleaners, building, compressor and engines, is not far from that of a steam plant complete, including boilers, engines, pumps, condensers, chimney, piping and all accessories, so we can assume the first cost the same in each case. As great pressures are not maintained in gas engine installations as they are in boiler plants, the depreciation from internal strains and corrosion should be considerably less. Gas engines do not wear out any quicker nor do they need any more repairs than steam engines. Gas producers are long lived, the apparatus requiring but little attention and few repairs. The Erie R. R. Co.

have had two 200 H. P. producers in operation at Jersey City for seven years and the fire in one has never been out. Imagine the condition of a boiler after such a run. Although the cost of operation including oil, waste, packing, purgers and labor would no doubt be less for the gas engine installation than for steam, no claims for savings are made on this account.

Stand by losses are much less in the internal combustion engine plant if run intermittently or if part of the equipment is held in reserve for immediate service. The gas holder with the producer provides for the peak of the load even though the producer is run at a uniform rate. With sufficient capacity of holder the gas producer may be run with a uniform output for every hour out of 24 though the engine load vary through the widest possible range and running under such conditions, there are practically no losses from radiation or leakage, as would exist in a boiler plant under pressure.

The California Gas and Electric Corporation, which normally gets its power from waterfalls two hundred miles away, carries a gasometer full of cold gas always in reserve for use in gas engine units, should the long distance power fail.

When compressed air is available, and all large units use this medium, gas engines of any size can be started and can take the full load in two minutes' time as no warming up or cylinder draining is necessary. The waste heat, about 70 per cent of the heat supplied, can be used for heating and a higher temperature can be maintained than with the heat from a steam engine exhaust. If the internal combustion engine has so many advantages over steam, why, then, has it not had greater development? Why are we not using gas engines in our large power plants? Why are we using 40,000 B. T. U. instead of 10,000 B. T. U. in generating a brake horse power? Why are we burning 400 cu. ft. of waste gases under our boilers to evaporate sufficient water for a horse power hour when 100 cu. ft. burned behind the piston would do the same work? Simply because the American manufacturers have not kept pace with the development of the gas engine as a prime mover.

Five years ago when Mr. Henry Wehrum, who has probably done more to introduce the gas engine for power for steel mill work in the United States than any other man, wanted one and two thousand horse power gas engines for the Lackawanna Steel Company's plant at Buffalo, there was practically but one engine obtainable and that of foreign make. A few months ago when the Carnegie Company wanted engines of the same size for the Edgar Thomson Works, twelve proposals were received from American manufacturers.

While the Europeans in order to manufacture at a profit, on account of the high price of fuel have been driven to the gas engine for power, the largest internal combustion engines ever made are of home product. It is said that a representative of the United States Steel Corporation went to Europe to investigate the gas en-

gine for steel mill work. After visiting several plants which were in successful operation, he said that they worked very nicely for small engines but he would like to see the largest engine ever built, whereupon he was advised to go home and see the 4,500 H. P. gas engine built by the Snow Steam Pump Works. This company has running and is having installed 25 internal combustion engines having a total capacity of 48,000 H. P. The largest engine ever built, a twin tandem 52 in. by 60 in., 5,400 B. H. P., is now being erected for the California Gas & Electric Corporation, and three others of the same size will follow.

The De La Vergne Machine Company have built nearly 50,000 H. P. of two and four cycle gas engines and have 40,000 H. P. installed in the Lackawanna Steel plant at Buffalo, N. Y.

The Westinghouse Company is installing engines of 2,000 H. P. and at least half a dozen manufacturers in the United States will take contracts for any size.

Such has been the growth of the internal combustion engine since 1900, yet the beginning of the present gas engine era, in the United States at least, dates from the expiration in 1890 of the fundamental four cycle patent of Dr. Otto. Of course there were several attempts to make commercial gas engines of the six-cycle or two-cycle type before this time, but with the exception of a few two-cycle marine engines and the imported Koerting, the other attempts have been abandoned. It would seem that the owners of so valuable a patent as that of the Otto cycle, while the protection lasted, would have used every effort to develop a large and remunerative business, but there are several reasons why more progress was not made by the owners of the American rights, while they enjoyed the exclusive monopoly of the only successful gas engine cycle at that time:

In the first place the firm itself was impregnated with a certain amount of Teutonic conservatism, which prevented the progress one would expect from a live American manufacturer; even the directions for using the Otto gas engine, a 16-page pamphlet, were sold for 25 cents a copy. Then again, only illuminating gas, which in those days cost more money than it does now, was available for fuel; and with a very high priced engine, upon which the general public looked with more or less suspicion, the advantages of the internal combustion engine over steam engines were questioned. But when it was found that the by-product of the refinery, gasoline and distillate, were available for fuel and the fundamental patent had expired, the era of the internal combustion engine began to dawn. Manufacturers who had been experimenting with engines of the two-cycle and Brayton type, began to build engines of the Otto cycle, and today there are upwards of five hundred manufacturers of gas engines in the United States alone.

The largest gas engine exhibited at the World's Columbian Exposition, thirteen years ago, was of only 35 H. P.

The opening of natural gas wells and the invention of practical

producers have provided a cheap fuel for the internal combustion engine, and the utilization of a by-product of the coke ovens and blast furnaces—an excellent gas engine fuel, have given the present impetus to gas engine manufacturers.

While the work done by the gas engine required no niceties of regulation, like driving a dynamo or textile machinery, a single cylinder engine with an impetus or blow when loaded every second revolution and when running light, once in a while, was a satisfactory source of power, but with the necessity of a better turning moment and better governing, more cylinders were added, thereby increasing the impulses per revolution, or the admission was throttled, reducing instead of the number of explosions, the mean effective pressure of each impulse.

As the highest possible compression without danger of premature ignition is conducive to the highest efficiency, the hit-and-miss method of governing is a more economical method than reducing the charge, but the advisability of a close regulation and uniform rotation makes the latter method imperative.

There are three dispositions of the heat in the fuel which goes into a gas engine cylinder: Part of it, usually about 25 per cent, goes into work, about 40 per cent into the water jacket and 35 per cent into the exhaust, radiation, etc. Now, if we can reduce the amount which is wasted, we of course increase the percentage turned into work; the amount going into the water jacket depends, other things being equal, on the amount of surface exposed during inflammation. The higher the compression the less surface surrounding the unit of compressed charge, therefore less heat goes into the work. The Lenoir engine, firing at atmospheric pressure, required nearly 100 cu. ft. of gas per B. H. P. hour, while with a compression of 5 atmospheres an engine of the same H. P. will do the same work on 20 cu. ft. of gas.

But the causes of efficiency in the internal combustion engine are worthy of a separate discussion, and even though infinitely more tangible than the complex losses of the steam plant, we will only refer to them as occasion requires.

As the exhaust stroke of a four-cycle, single-acting engine has no compression to bring to rest the reciprocating parts and as a triple or quadruple crank is not only expensive to build and maintain in alignment, but as the work on one crank must be transmitted through other cranks, there arose a demand, in the minds at least of engineers, for a double-acting gas engine, which, if made tandem, even with the four-cycle, would give not only an impulse for every stroke, or twice during a revolution, but the reciprocating parts would be brought to rest by the compression indigenous to each stroke.

A 60-H. P. engine, embodying these features, designed in 1897, was, to my knowledge, the first successful double-acting engine ever built, though Dick Kerr & Co., of Kilmarnock, Scotland, had built a few both four and six cycle tandem engines, two of which had a

brief existence in a central lighting station at the corner of Clark and Lake streets, Chicago, in '95 or '96.

At the Paris Exposition in 1900 a 1,000 H. P. single-acting, single cylinder Cockerell engine was shown, but the double acting tandem engines now building by most European and many American manufacturers, were conspicuous by their absence. With a tandem construction, with a single crank we can get as many impulses as with a single cylinder steam engine, and with a twin tandem, as many impulses as with a cross compound engine. With this type, approaching as it does the steam engine design, the driving of multiphase generators in parallel is readily accomplished.

It has been previously stated that the higher the compression within the limits of the pressure necessary for premature ignition, the greater the efficiency, but the kind of fuel governs the degree, and the compression necessary to ignite kerosene vapor, while not so volatile as gasoline, will not cause the latter to burn. Natural gas can be compressed to 150 pounds absolute, alcohol vapor to 190 pounds and blast furnace gas to 210 pounds and still require an electric spark to start inflammation.

The other loss of heat in a gas engine besides that which is transmitted to the water jacket is the heat which goes out with the exhaust. When a cylinder full of gas and air is compressed and ignited, the chemical action generates an intense heat; the gases expand one-four hundred and ninetieth of their volume for every degree of Fahrenheit and the chemical action even with a proper mixture is not instantaneous and often there is flame coming out with the exhaust.

If a full cylinder of combustible mixture is compressed from atmospheric pressure and temperature and heated further by chemical action, then when the volume is constant the pressure is increased and the release of this pressure when the exhaust valve opens causes the familiar "sea lion bark," always associated with the exhaust of a gas engine. This is the second loss of the internal combustion engine and when we consider that from 35 to 40 per cent of the heat is wasted in this way, is it any wonder that engineers have tried to minimize this loss? We all know the inefficiency of the direct acting steam pump and the gain by a more complete expansion, even though we get a lower mean effective pressure and consequently less power from the same cylinders. To utilize the heat and pressure in the exhaust, compound gas engines have been suggested, tried, and in some cases shown an increased efficiency.

If steam were a perfect gas, void of cylinder condensation, an early cut-off in a single expansion cylinder would give as many expansions and as good economy as we get in the compound engine. The working fluid of an internal combustion engine is practically a perfect gas, therefore the efficiency of this type of prime mover may be increased if we can expand the working charge to a greater volume than is compressed.

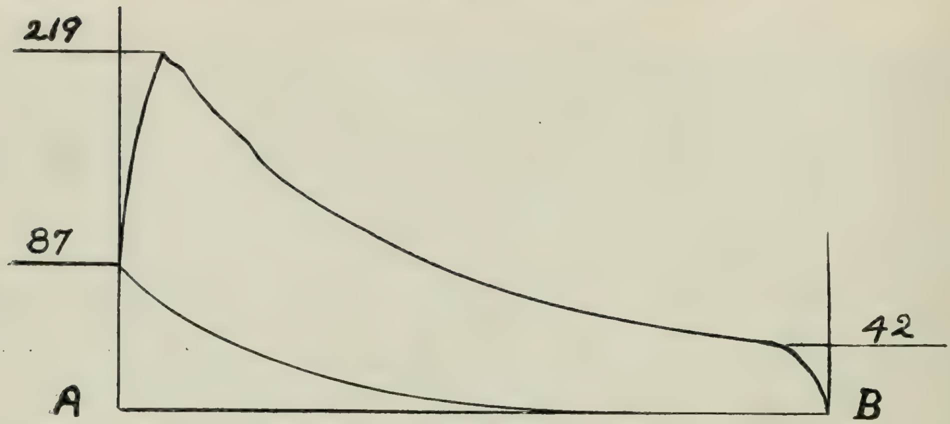



Fig. 1

To illustrate in a language familiar to the engineer: Fig. 1 is an indicator diagram from the ordinary Otto cycle gas engine of a popular make. In this diagram the compression is carried to 87 pounds above atmosphere, and after ignition and inflammation the pressure is released at 42 pounds above atmosphere or 57 pounds absolute. Now, to increase the efficiency of this type of prime mover, the double acting tandem engine previously referred to, was designed to give the diagram shown in Fig. 2 where A B

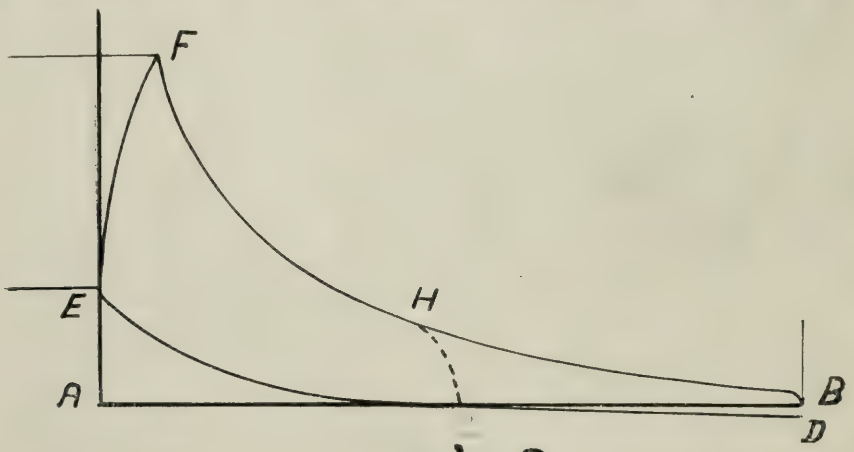



Fig. 2

represents the atmospheric line and length of stroke; with the average load the combustible mixture is drawn in at some predetermined point, C, where the admission is cut off and rarified during the remainder of the stroke; the line C D showing the pressure below the atmosphere. No work is lost in this rarefaction, and on the return stroke the compression above the atmosphere begins at C, reaching a predetermined pressure at E; F E is the firing line and F B the expansion line, the release at B being slightly above atmospheric pressure. Instead of releasing at H, as in the ordinary gas engine, the expansion is nearly double the admission, and the area C H B C represents the increased work

for the same quantity of fuel and measures on the diagram from 22 to 25 per sent. No muffler is required and the temperature of exhaust is reduced about 1,200° F. below that in the ordinary gas engine. The point of cut-off C, is controlled by the governor moving toward A as the load gets lighter and the speed tends to increase, thereby reducing the quantity of the combustible mixture and necessarily the mean effective pressure. If the load gets heavier and the speed tends to decrease, the point C moves toward B, thereby taking in a larger quantity of the mixture, raising the mean effective pressure, and the pressure of release. If the point of cut-off C gives the highest efficiency at full load, then with an over-load or under-load, the efficiency will be decreased.

As in a steam engine, there is a limit to the degree of expansion desirable. When the pressure equals the power required to overcome the friction, a further expansion reduces the efficiency of the engine. For this reason an engine decreases in efficiency as the load gets lighter. In a single expansion steam engine it has been found that a terminal pressure of about four pounds above the atmosphere is the most efficient pressure of release while on account of the lower mechanical efficiency of the gas engine a terminal pressure of from 6 to 8 pounds seems to give the greatest economy.

Fig. 3

In Fig. 3 is shown a diagram from this engine, with a variable load, in which the expansion line of the smallest diagram approaches the line of highest compression, yet the highest and lowest compression lines show but little variation. The compression varies directly with an overload and must not get beyond the critical limit of self-ignition, yet the design of the engine is such that the compression only reduces one-half as fast as the cut-off, so that we maintain the highest maximum economy during the wide range of load.

There is shown in Fig. 5 a light spring diagram taken with a stop from a double acting engine operating on this cycle, and Fig. 6 shows a constant load diagram of 50 explosions in which the release is practically atmospheric, while Fig. 7 shows diagrams from both ends of a cylinder of the same engine, slightly overloaded.

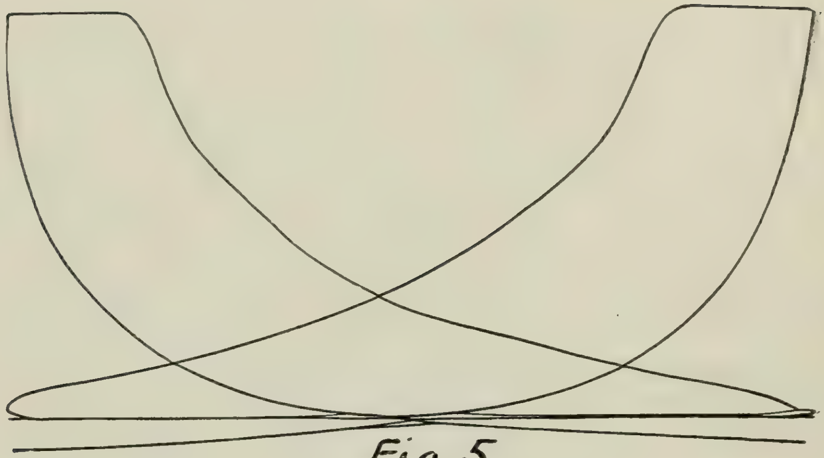


Fig. 5


Fig. 6.

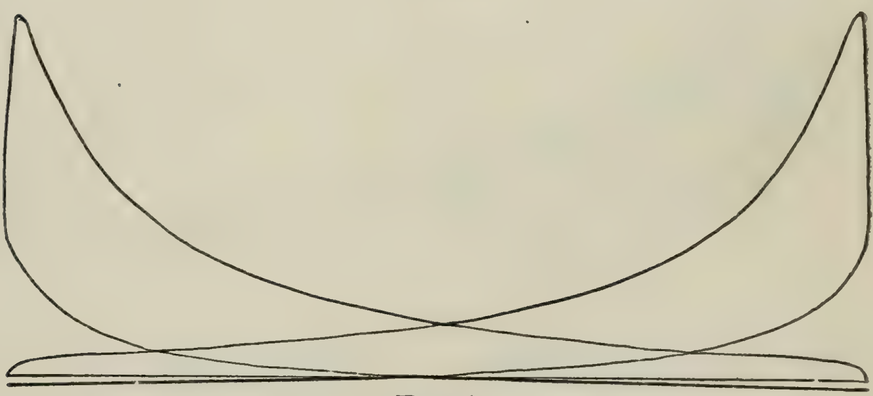


Fig. 7

DIAGRAM SHOWING CHANGE OF LOAD

Fig. 8.

If the time of ignition is such that with a full load the firing line is vertical, or what is better, leaning about 10° from the vertical, a shown in Fig. 2, as the load gets lighter, the charge is reduced by either cutting off earlier, throttling or admitting less gas, depending on the type of engine, but as the products of combustion which fill the clearance space do not decrease, the mixture gets weaker, inflammation gets slower and the piston will often travel as fast as the rise in pressure.

Fig. 8 is a variable load diagram of an ordinary throttling engine with a fixed point of ignition from which we see that as the load gets lighter the initial pressure approaches that of compression. As the greatest heat corresponds to the greatest pressure, you will note that the cylinder surface increases so rapidly, as the piston advances in the stroke, that the flame is cooled down as fast as it is propagated. This causes a loss of efficiency which is overcome in engines advancing the time of ignition with the cut-off.

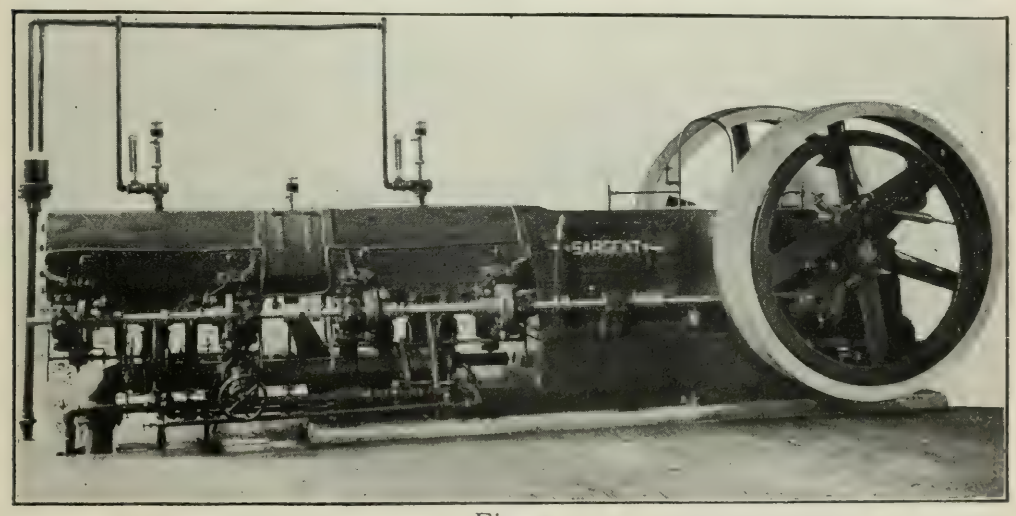



Fig. 9.

In Fig. 3 the highest initial pressure remains where the cooling surface is least, maintaining a much higher efficiency than with a fixed ignition. The engine from which these diagrams were taken is shown in Fig. 9, where the charge is expanded to a terminal pressure which gives the greatest efficiency. varies the point of cut-off with the load and advances the time of ignition as the inflammation gets slower. This is a 10 in. by 20 in. tandem, double-acting 50 H. P. engine, good for a 20 per cent over-load without dropping in speed. The frame is enclosed and self-oiling, without the crank or discs dipping into the oil. The side shaft is driven by a Rites governor and is advanced or retarded in time ahead of the crank shaft as the load varies, maintaining a regulation within 2 per cent between full and no load. Fig. 10 represents a section through the crank shaft of this engine and shows the worm gears which drive the side shaft. The driving gear is loose on the main shaft and is advanced or retarded relative to the shaft by the governor,

depending on the load. The driven gear keyed to the side shaft opens or closes the valves earlier or later, maintaining thereby a

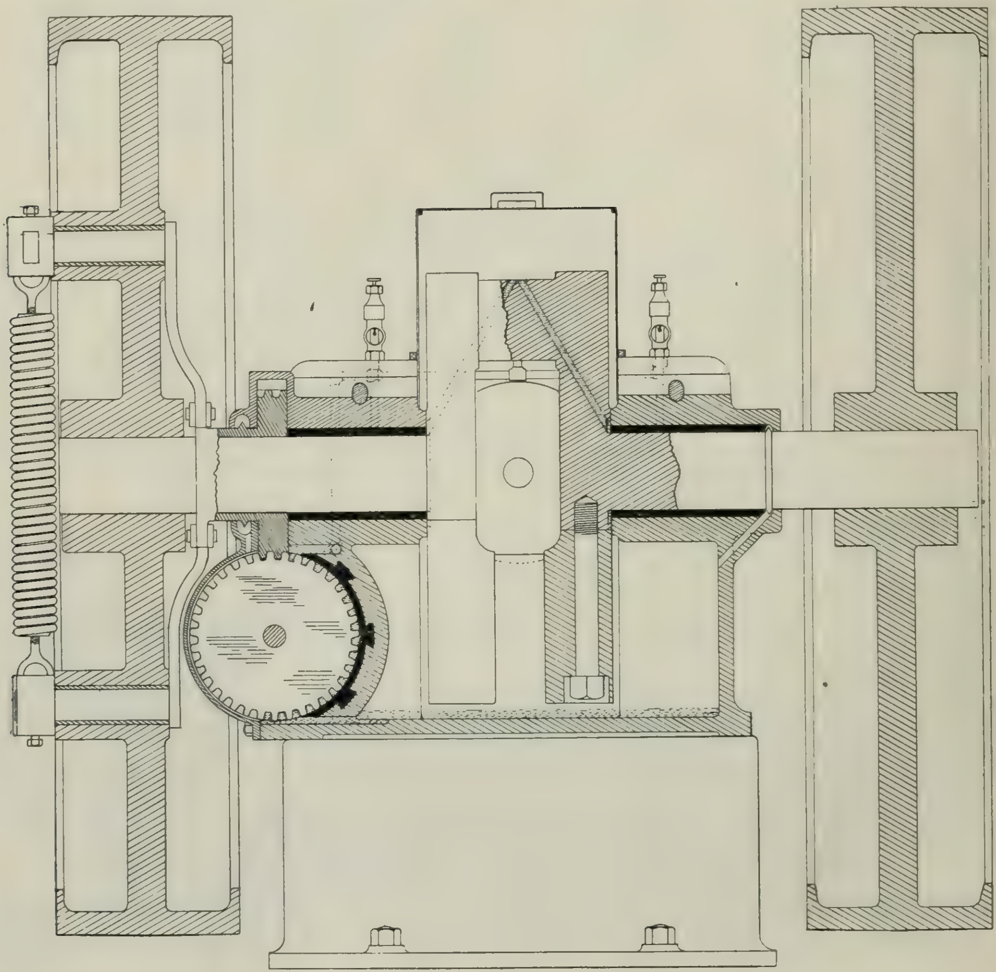


Fig. 10

uniform speed. As these gears should run in oil to be efficient and as the engine bearings have to be copiously lubricated, the oil flows into the spaces between the teeth and is pumped through pipes to all moving parts. Fig. 11, is another view of the same engine driving a 40 K. W. generator. Shortly after this engine was publicly described there seemed to be a universal movement among the larger gas engine builders, both at home and abroad, towards horizontal, tandem, double acting engines, and practically all the larger engines now built are of this type.

A diagramatical, horizontal section of a 500 H. P. two cycle Koerting gas engine is shown in Fig. 12, as built in the United States by the De La Vergne Machine Co., of New York, shows the exhaust-port at the middle of the cylinder and the air and gas pump in section; while Fig. 13 shows an elevation of the same engine with its secondary crank and gas and air cylinders in the foreground.

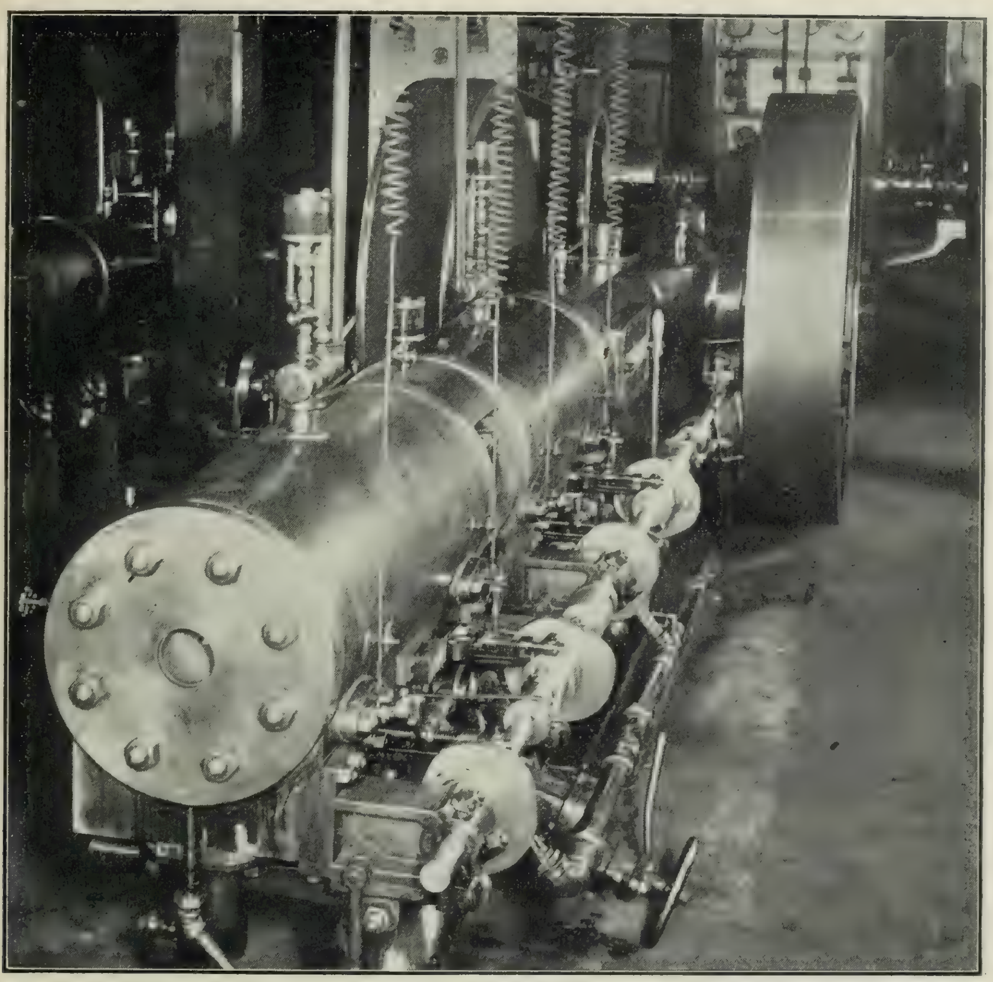


Fig. 11.

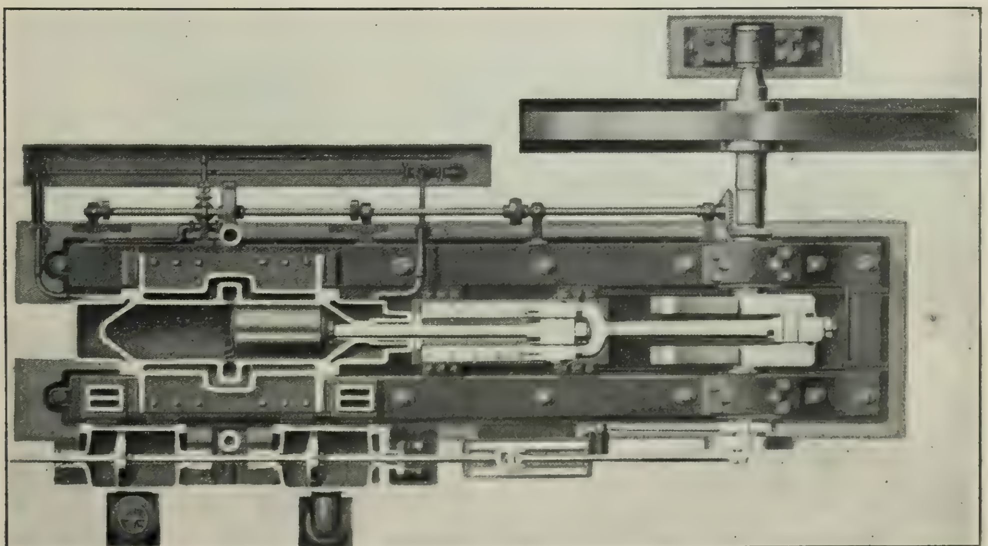


Fig. 12.

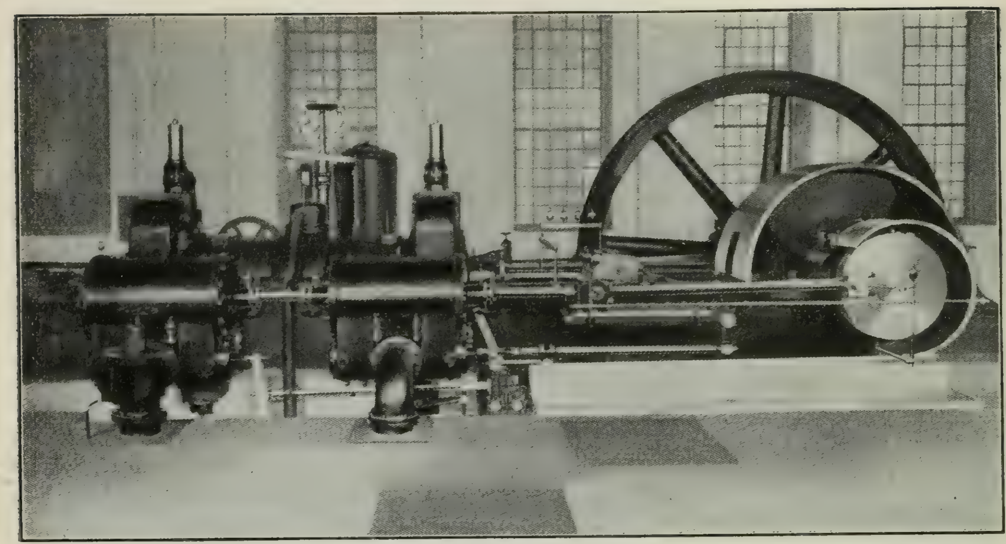


Fig. 13.

The Lackawanna Steel Co., of Buffalo have over 40,000 H. P. of gas engines of this type installed in their works, running on a by-product of the blast furnace, "furnace gas," the combustible matter of which is mostly carbon monoxide. This steel plant has the largest gas-engine installation in the United States, and is well worth a personal visit and inspection. The Koerting engine has three cylinders where the four cycle tandem has but two for the same number of impulses, but it has several advantages as well as disadvantages over engines using the Otto cycle.

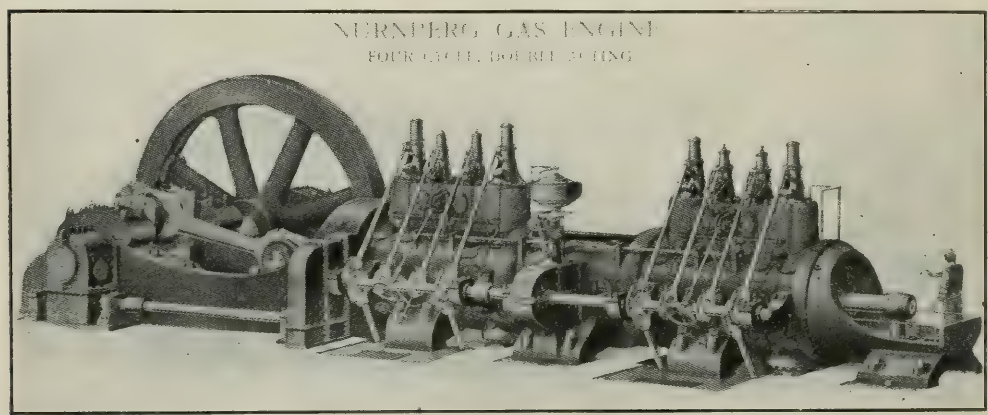


Fig. 14.

In Fig. 14 is shown an American edition of that most excellent German engine, the Nurnberg, which is built by the Allis-Chalmers Co. in sizes up to 6,000 H. P. This is a double acting tandem engine, each explosion chamber having three valves, one exhaust on the bottom and one air and one gas on the top. The method

of governing is by reducing the gas and increasing the air, varying the proportions but keeping the compression constant. Fig. 15 shows a section through a valve chest of one end of one cylinder of this engine as formerly built, and after counting the valves, cams, levers, links, springs, rollers and moving parts, the old cry of the gas engine salesman and manufacturer, that no engineer is needed, appears more ridiculous than ever.

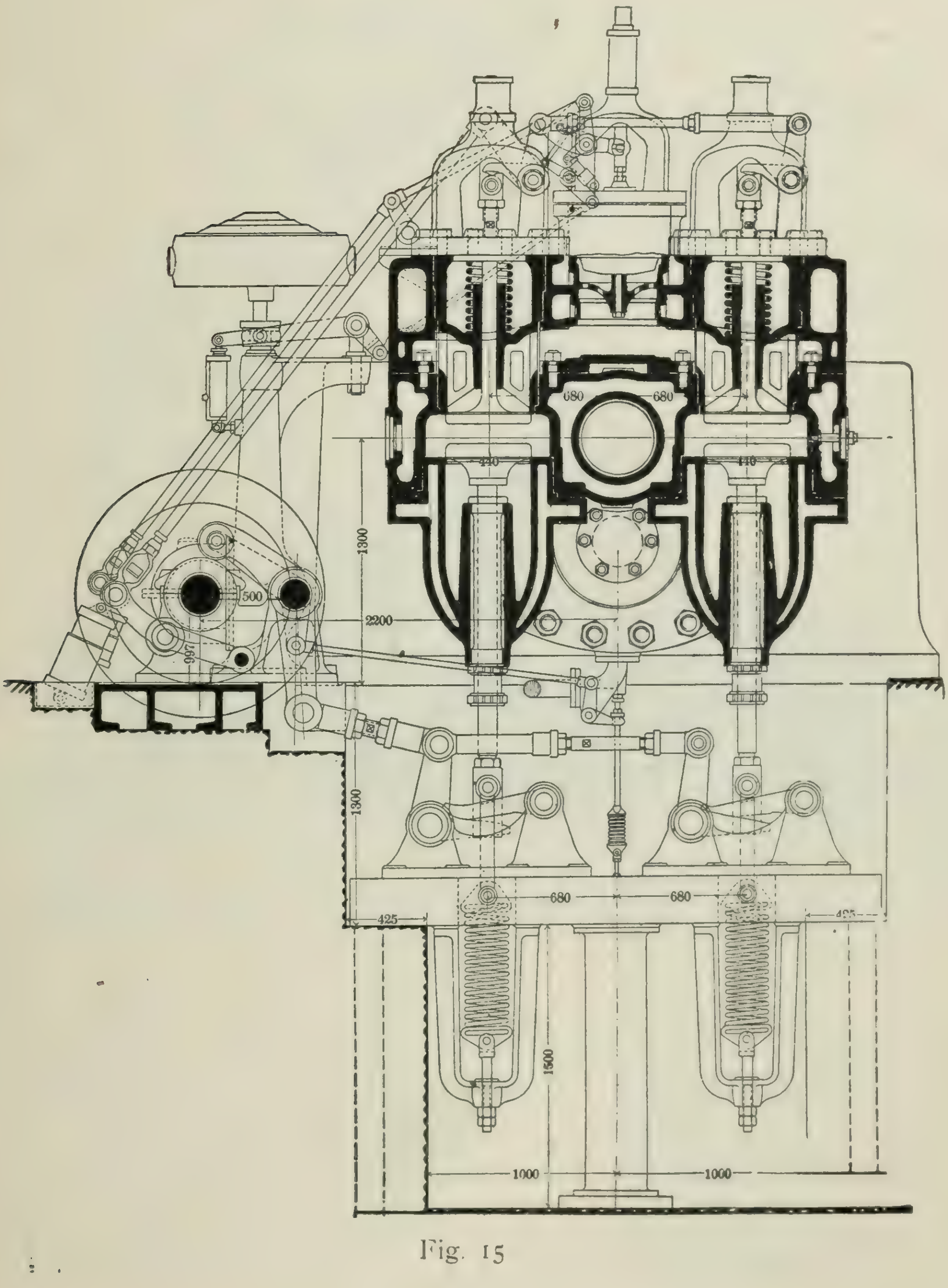



Fig. 15

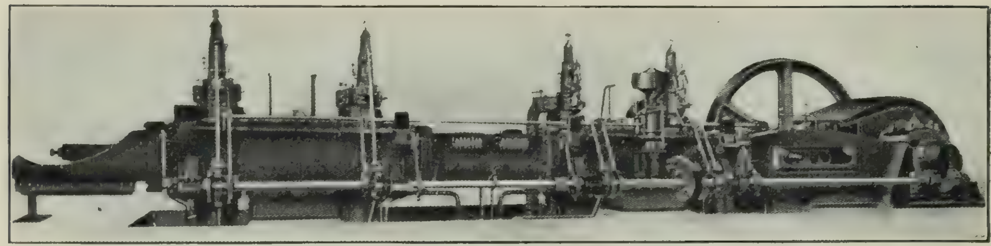


Fig. 16.

Fig. 16 shows the latest designed Cockerill gas engine as built abroad, and this engine is now being manufactured in the United States for blast furnace gas by the Wellman-Seaver-Morgan Co., of Cleveland, Ohio. Cockerill & Sons were the pioneer builders of large engines for blast furnace gas, and no doubt have done more than any other manufacturer to develop the internal combustion engine for steel mill plants.

Since the Paris Exposition in 1900 these engines have been built tandem and double acting and the latest valve motion of this engine is shown in Fig. 17. The combustible mixture is admitted at the top and discharged through the exhaust valve on the bottom. About 100,000 H. P. of Cockerill engines are in successful operation in Europe.

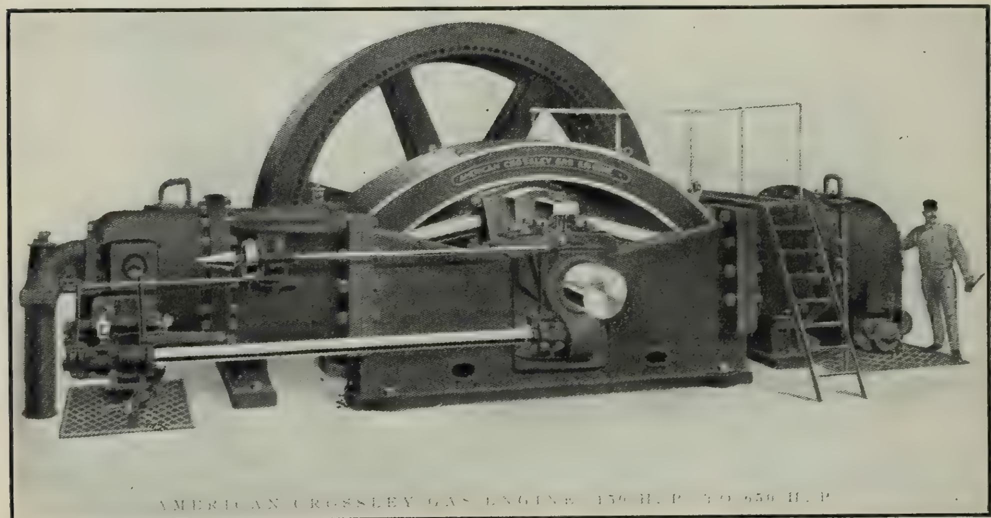


Fig. 18.

In Fig. 18 is shown a 650 H. P. American Crossley engine, manufactured by the Power & Mining Machinery Co., now of Cudahy, Wisconsin, builders of the Loomis-Pettibone gas producers. This engine is built as a single and opposed cylinder engine, and with four opposed cylinders and two cranks the same impulses are obtained as with the double acting tandem engine. Other things being equal, an engine of this type is more economical than a tandem engine, but the actual floor space occupied is probably a little more.

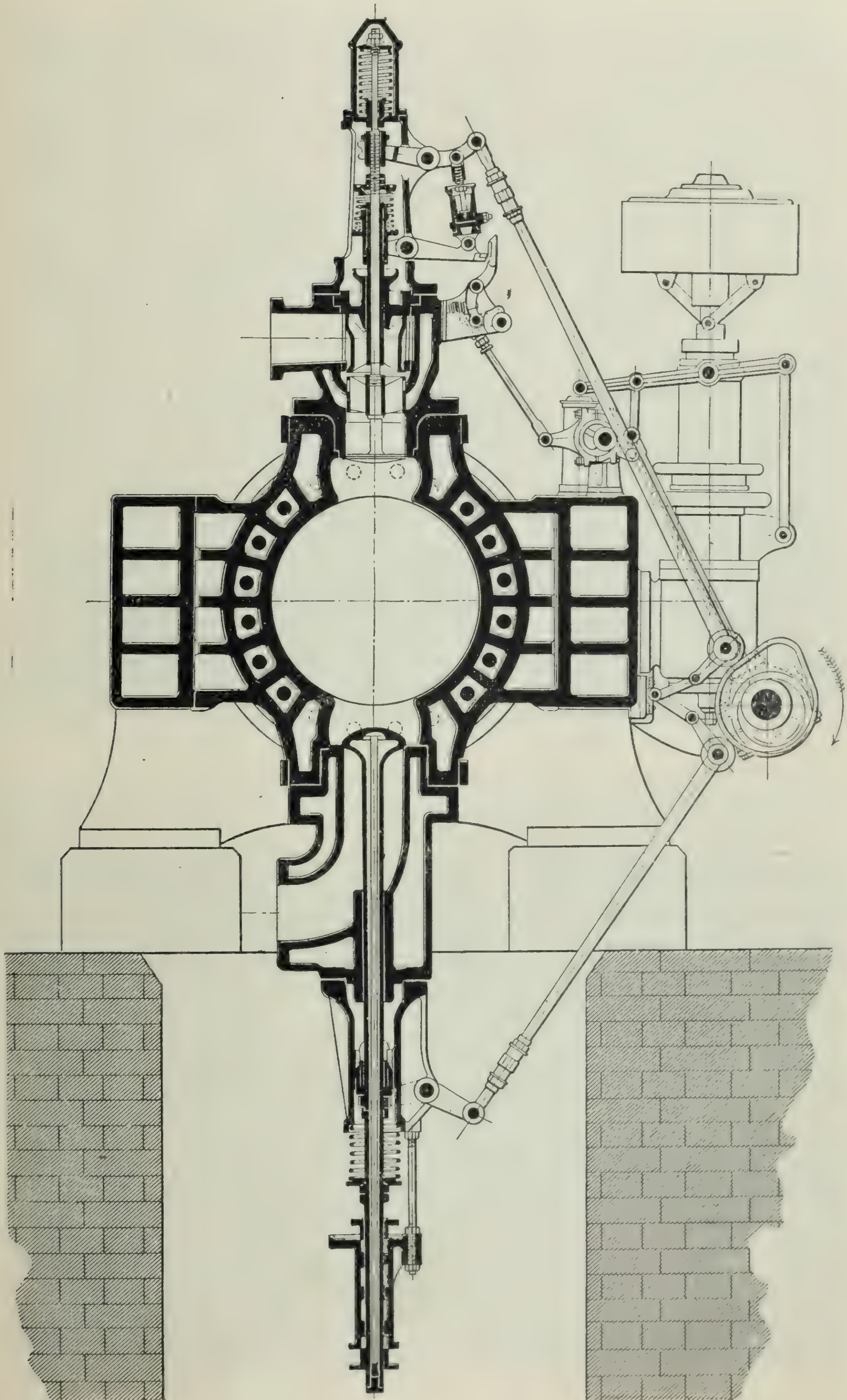


Fig. 17.

Fig. 19 is an American product and the latest designed horizontal tandem double-acting gas engine of the Westinghouse type. This company makes vertical single-acting trunk-piston gas engines up to 650 H. P., and their catalogue used to say piston rods in gas engines were impracticable, but now they build engines of the tandem horizontal type from 200 H. P. up to 3,000 H. P., if not larger. You will note that the valves in this design are on the top and bottom of the cylinder, admitting direct to the explosion chamber without the long, narrow combustion chamber in their first design. This design conforms to European practice and a higher thermal efficiency should be obtained on account of the better shape of the combustion chamber.

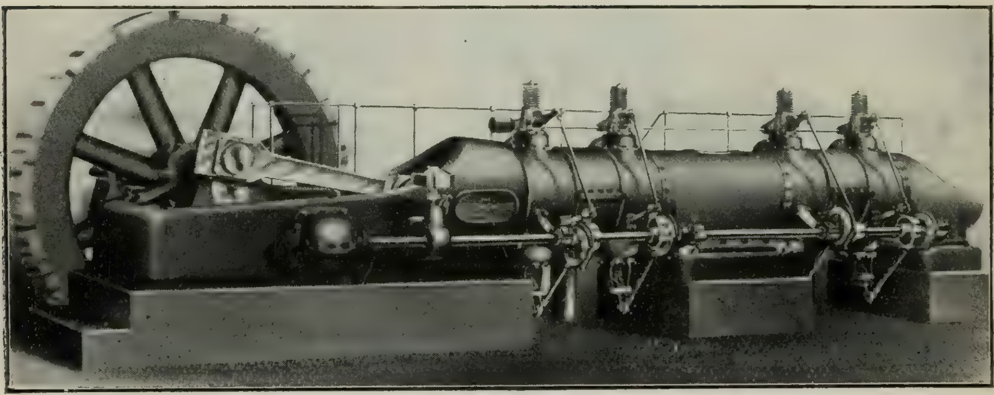


Fig. 19.

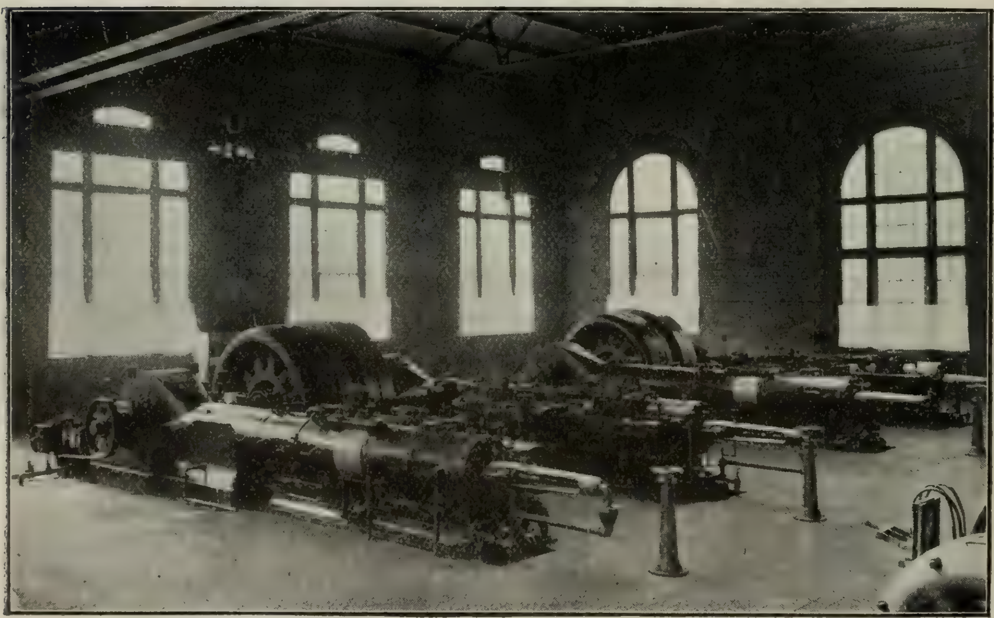


Fig. 20.

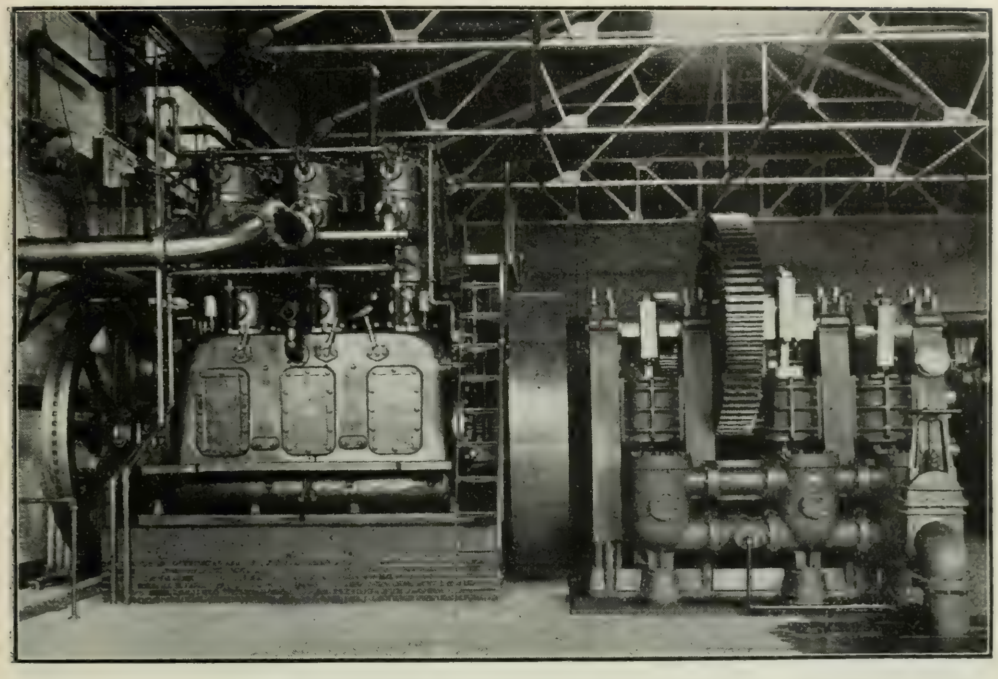


Fig. 21.

In Fig. 20 is shown a power plant, consisting of two 500 H. P. old style twin tandem, direct-connected gas engines at the Atlantic Refining Co., Philadelphia, driving alternators in parallel.

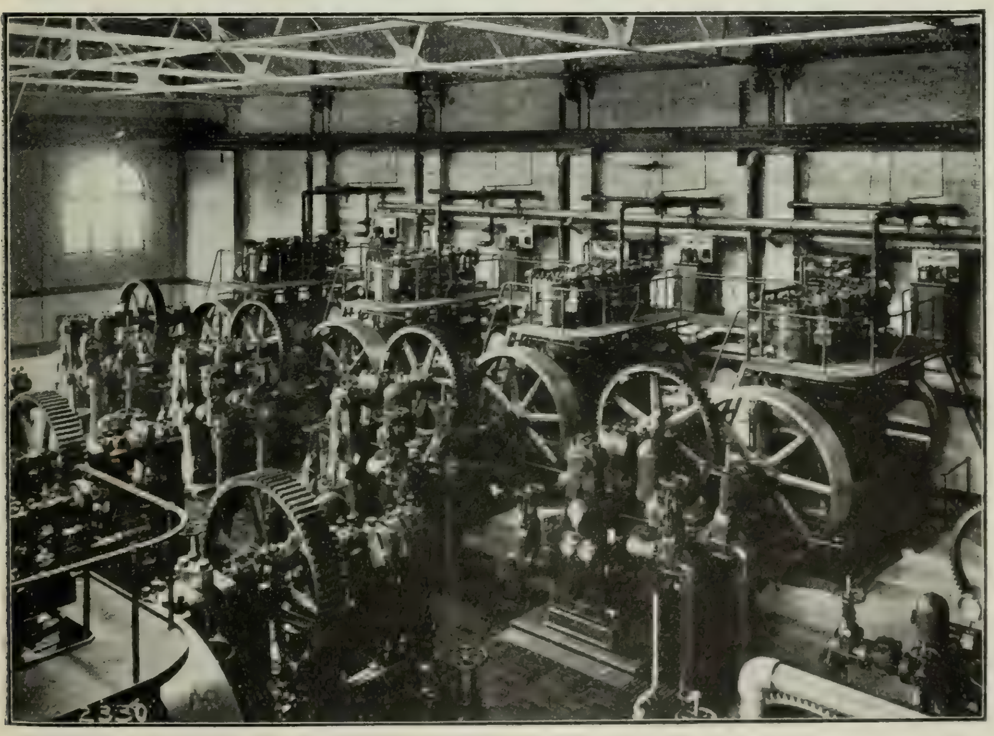


Fig. 22.

On account of the ease of starting a gas engine, the minimum time taken to start it and that there are no stand-by losses when not running, gas engine pumping plants for water works and fire service are used with excellent satisfaction. Fig. 21 shows one of the 300 H. P. Westinghouse engines direct connected to a triplex-pump built for a high pressure pumping station in Philadelphia and Fig 22 is a view of the interior of this station. I am told that these engines and pumps can be put in commission within two minutes after a fire alarm comes in. Fig. 23 shows three vertical engines driving alternators in parallel in the power house of the Westinghouse Machine Co., a case of practicing what you preach.

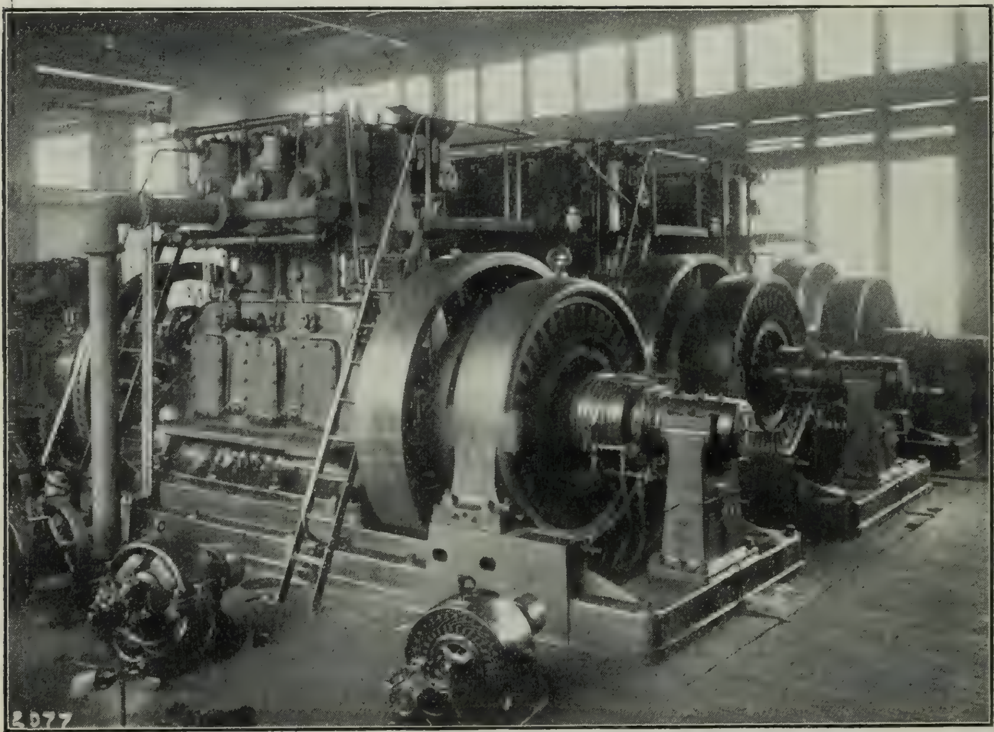


Fig. 23.

Fig. 24 is a three cylinder 300 H. P. Struthers-Wells engine made at Warren, Pa., and Fig. 25 shows two 800 H. P. four cylinder engines made by the same company. These are the largest vertical single-acting gas engines ever built and with anthracite culm and gas producers they delivered a brake horse power at the cost of 1.5 mills per hour, for the cost of fuel only.

Fig. 26 shows a double opposed four cylinder, 32 in. by 36 in. single-acting American Crossley engine, which was installed at Elmira, N. Y. This engine is rated at 1,500 H. P.

The views of the two cycle engines so far seen, have been of the plain side showing the drag crank and gas and air cylinders. Fig. 27 shows the lay-shaft side of a two cycle engine the great claim

for which, as made by the manufacturer, is simplicity and the elimination of exhaust valves.

Fig. 28 shows five 2,000 H. P. twin Koerting, horizontal engines, each driving a vertical blowing cylinder, furnishing air for blast furnaces. The air is drawn into the blowing cylinder, forced through the stoves and blast furnace, then with its carbon mon-

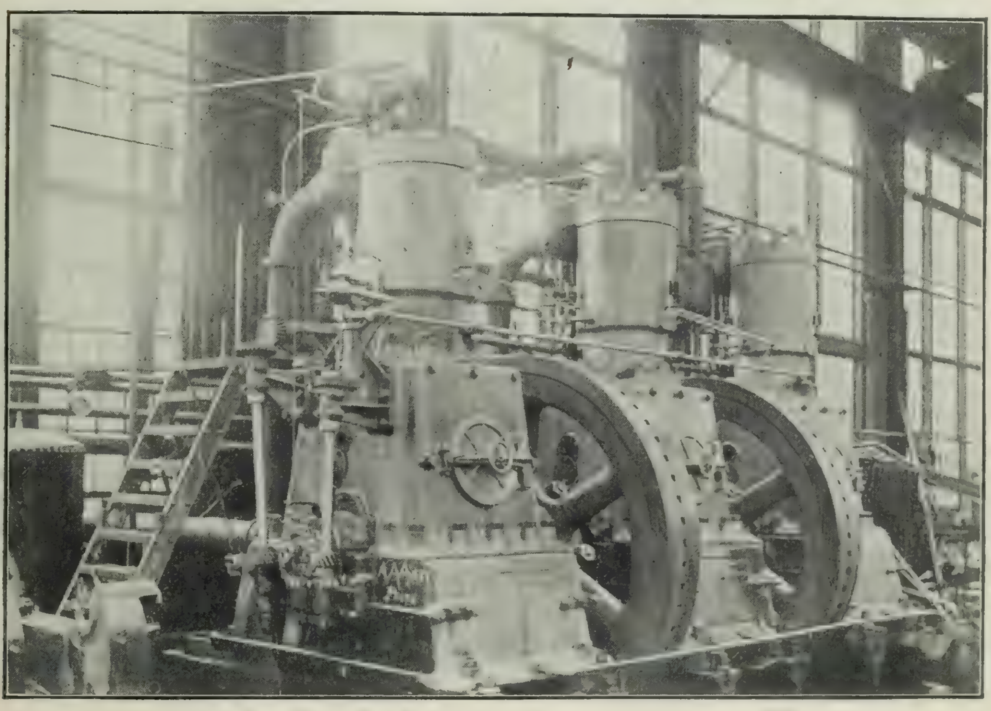


Fig. 24.

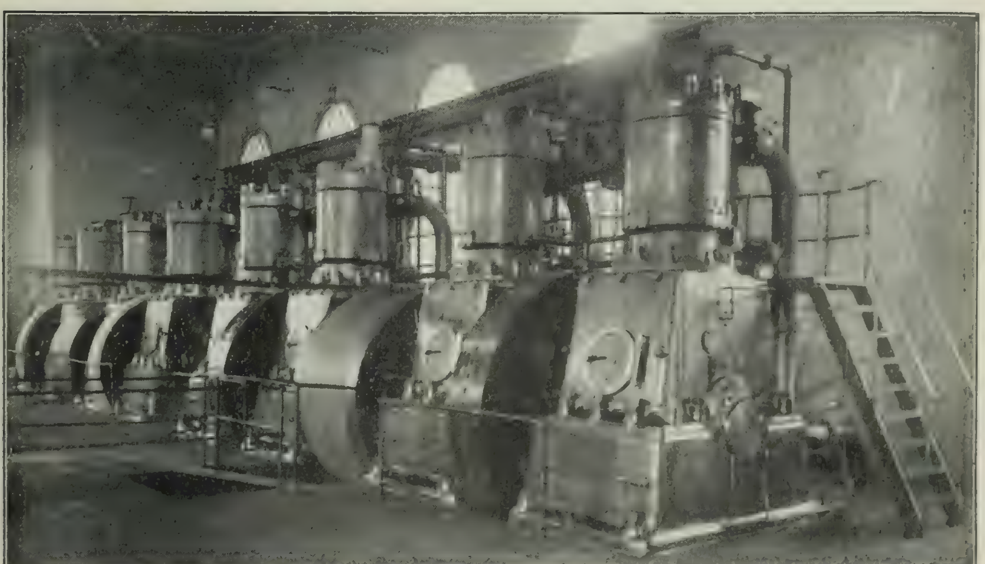


Fig. 25.

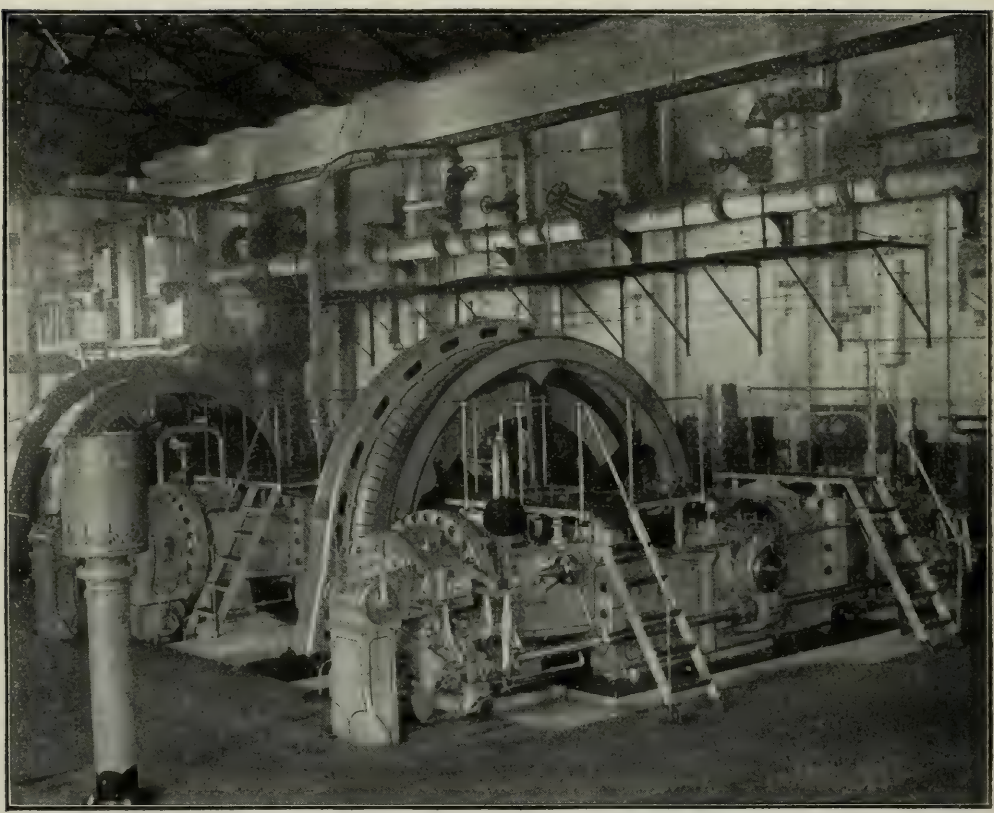


Fig. 26.

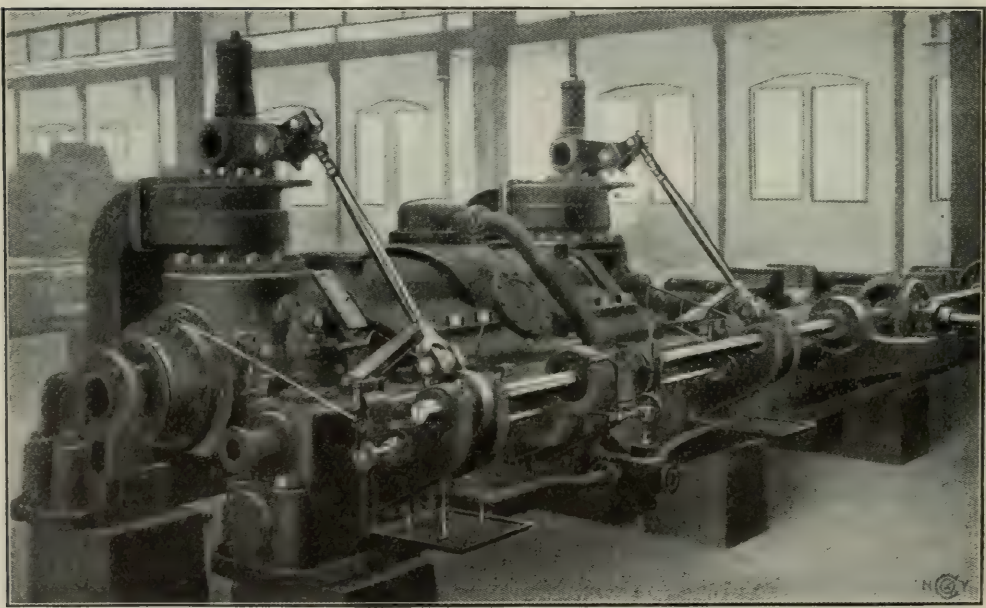


Fig. 27.

oxide gathered in the cycle, is burned in the power cylinder which drives the compressor. Fig. 29 shows the same type of engine with a horizontal blowing engine in tandem with the gas engine cylinders.

Even with an impulse for every stroke, on account of the high initial pressure and the variable mean effective pressures indig-

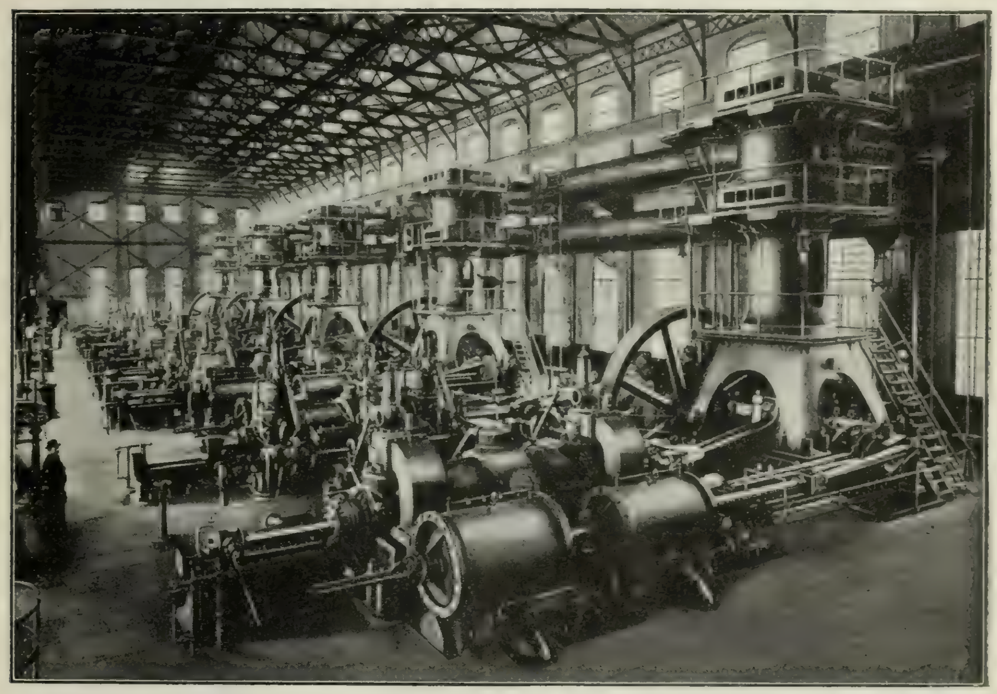


Fig. 28.

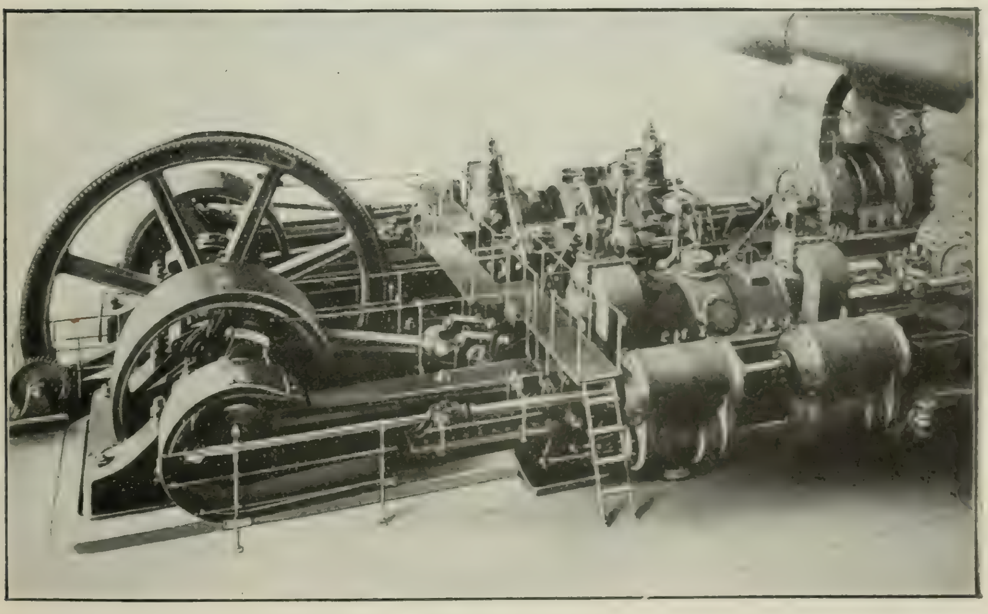


Fig. 29.

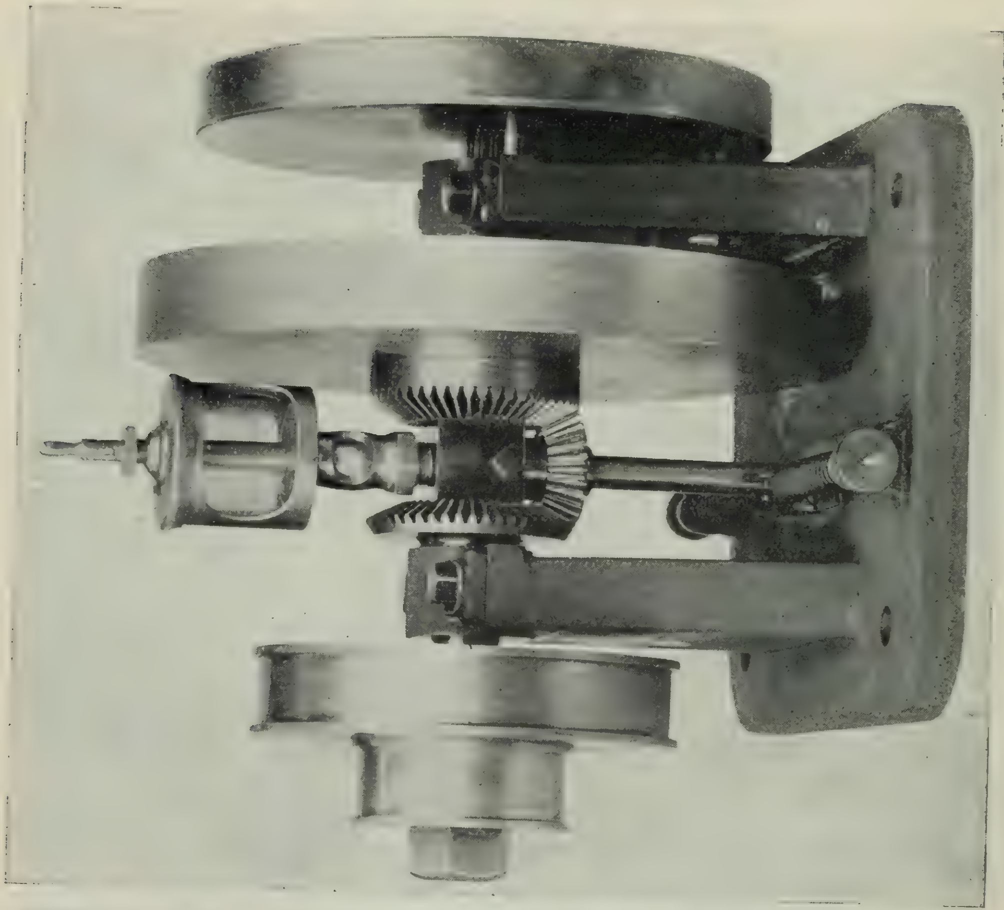


Fig. 31

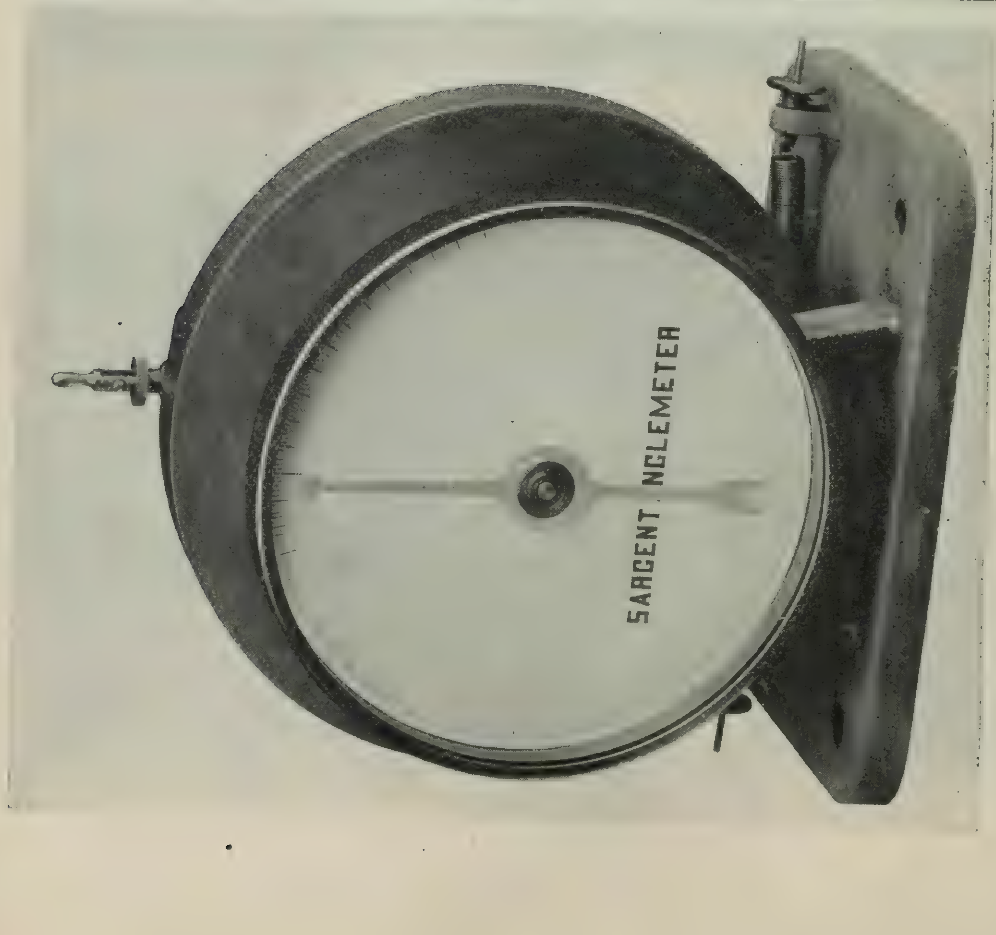



Fig. 30.

enous to all internal combustion engines, heavier fly wheels are required than with steam engines to get an equal minimum angular velocity variation, which is an essential condition for the parallel operation of multiphase generators. A device to determine this angular velocity variation for the fly wheel of any prime mover, was designed and the operation of the same was so satisfactory in its indications of the variable impulses received under adverse conditions, that an illustration of the same in this connection does not seem out of place.

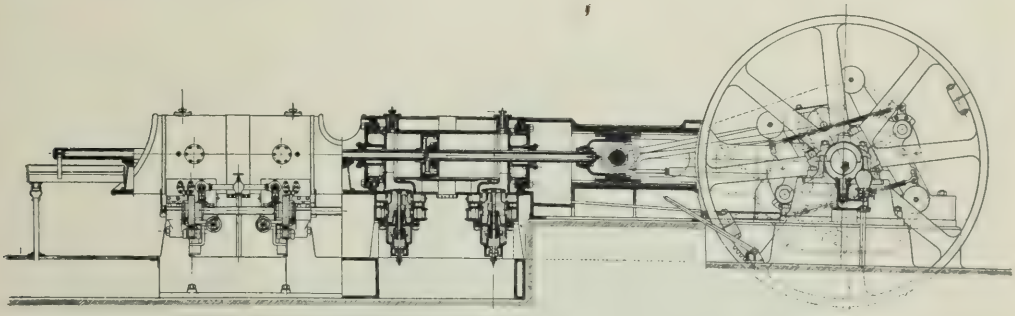


Fig. 32.

Fig 30 shows the dial of this instrument and as the movement of the needle is multiplied 360 times, should the fly-wheel of the engine vary one degree during a revolution, the needle would describe a semi-circle each side of the zero point equalling one degree. Each large division is one minute and each small division is six seconds. Fig. 31 shows the side elevation of the anglemeter consisting of a fly-wheel, intermediate pinion and the light pulleys which are driven by a flexible inelastic belt from the engine shaft. The fly-wheel is kept in uniform motion by the tension of a hair spring and the difference in angular velocity is indicated by the needle of the dial. The device is useful to check the mathematical calculations of fly-wheel variation.

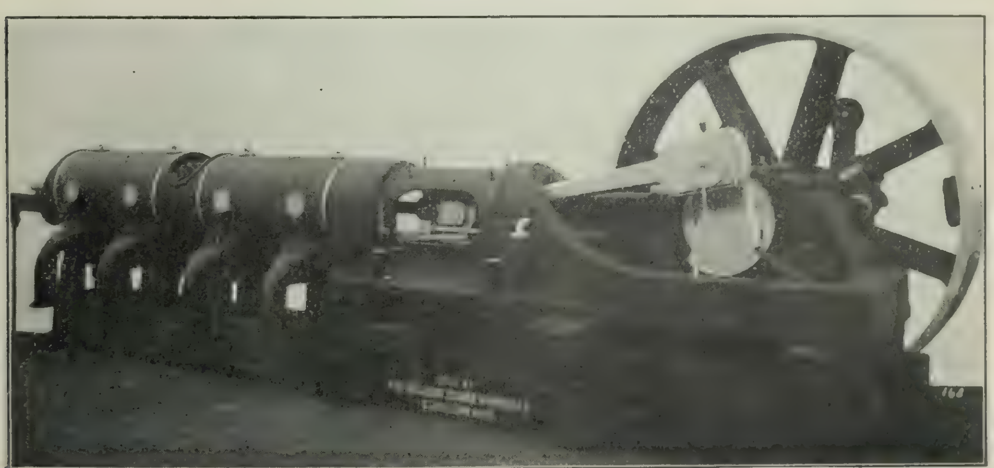


Fig. 33.

Fig. 32 shows the elevation of a 500 H. P. engine, the rear cylinder in full and the front cylinder and main frame in section. As I know more of this engine than the others, you will pardon me for going deeper into the details of the design. Fig. 33 shows the plain side of the same engine. The cast iron pipes from each explosion chamber carry the burnt products to the exhaust header and by using a side crank the main shaft is carried in but two bearings. All engines heretofore shown, with the exception of the latest designed Westinghouse, have had three and four bearings to support the crank shaft. Fig. 34 is a view of this engine from

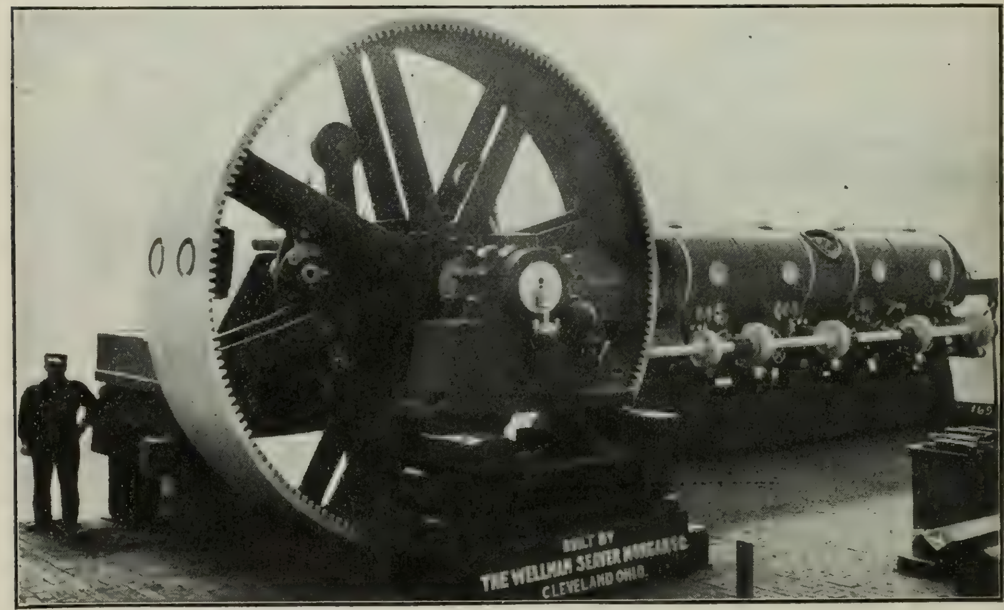



Fig. 34.

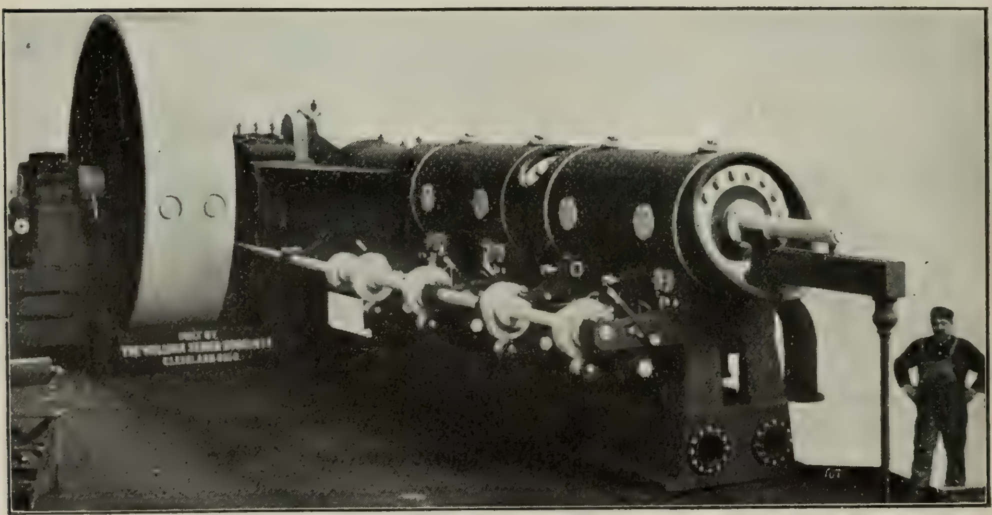


Fig. 35.

the fly-wheel end and Fig. 35 is a view of the side shaft side of the engine, taken when on the erecting floor. The engine was jacked up so that the fly-wheel would clear the floor, which makes the height of engine unusual. The floor line of the engine room comes at the top of sub-base containing the air and gas inlet. Air and gas pass up separately to the cylinder through the hollow legs upon which the cylinders rest and upon which they can come and go with a variation in temperature caused by changes of load.

The gas, water, air and exhaust come under the floor and no pipes other than those shown are seen. The double-arm Rites governor seen in the fly-wheel is direct-connected to the side shaft and advances the same in time ahead of the main shaft as the speed increases. There is but one cam, one roller and a single poppet valve for each explosion chamber. The engine is started by opening a 2-inch valve admitting compressed air to one cylinder and after one or two revolutions the air is cut off and gas valves are automatically put in commission. Fig. 36 is a section through the valve chest of one end of one cylinder showing the single poppet valve for both admission and exhaust and all the mechanism used to admit, cut off, hold in during compression, fire and exhaust, the combustible charge.

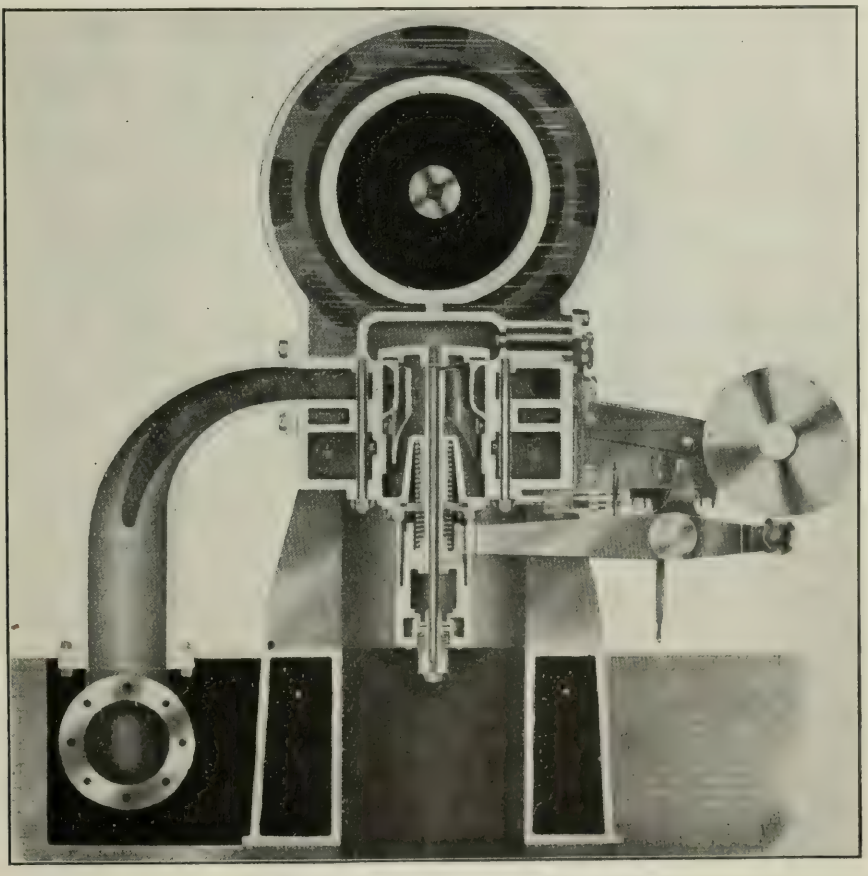


Fig. 36.

Every large engine shown tonight has been developed within the past five years. The experimental stage has passed, internal combustion engines have come to stay. Steam turbines, reciprocating steam engines and water wheels have their place, but the internal combustion engine is destined to be the prime mover of the future.

DISCUSSION.

*President Carter*—I have enjoyed listening to this exceedingly interesting paper, and if any of the members or guests here tonight wish to ask Mr. Sargent any questions, or offer any discussion, we shall be very glad to hear from them. The paper is now open for discussion.

*A Visitor*—What do you think is the outlook, Mr. Sargent, for the gas turbine?

*Mr. Sargent*—I have had but little experience with gas turbines. I know they have been tried and that some of them work satsifactorily from a mechanical standpoint, but with very poor efficiency.

*A Visitor*—At what speeds do these larger engines run?

*Mr. Sargent*—All the way from 600 to 1000 feet piston speed. If the piston speed were 1,200 feet per minute, there would be still greater economy. The time of inflammation is very short, and it is desirable to utilize the pressure which follows as quickly as possible, if a high thermal efficiency is desirable.

*Mr. Carter*—Between what limits is the number of revolutions on the 1,000 H. P. and larger engines?

*Mr. Sargent*—For a 48-inch stroke, 75 to 110 revolutions per minute are the limits.

*A Visitor*—How is the 1,000 H. P. engine started?

*M. Sargent*—A tank of compressed air—enough to give a few impulses—is the power used for starting. By opening a valve, the pressure of the compressed air puts in commission the starting mechanism and throws out of commission the gas engine apparatus. The engine is started by this compressed air in one cylinder; as soon as the other cylinder gets an explosion, the air is shut off by the operator, the starting mechanism is automatically thrown out of commission, and the gas valves are thrown in. All you have to do to start a 1,000 H. P. engine, is to open a 2-in. valve for about ten seconds and close it again, and the engine is in commission. The cooling water can be turned on before or after the engine is started.

*A Visitor*—How many horse-power did that large Snow engine develop in service?

*Mr. Sargent*—When I saw it, it was developing about 3,000. H. P.

*Mr. Mayer*—(M. W. S. E.)—What success has the Diesel engine been meeting in this country, so far?

*Mr. Sargent*—It is pretty hard to tell; it does not seem to be coming to the front very fast. There has been a great deal of experimenting, and lots of money has been spent in the development

of the American Diesel engine, but it could hardly be called a commercial success until quite recently. At the present time this company is selling quite a few engines. I know of a plant containing one 500 H. P., and two 250 H. P. and one 120 H. P. I expect to test one of the 250 H. P. engines for thermal efficiency in about a month.

*Mr. Mayer*—The high efficiency obtained is at the expense of repairs, is it not?

*Mr. Sargent*—On account of the very high compression in the Diesel engine, necessary for spontaneous combustion (500 to 550 pounds), it is necessary to maintain about 1,100 pound of air pressure to successfully force in the fuel oil, and on account of this very high pressure there have been accidents, but the economy of the Diesel engine has never been equalled by any engine of its size.

*Mr. Carter*—Is the action that takes place in the cylinder of a gas engine, a true explosion?

*Mr. Sargent*—No, it is slow combustion, that is, it is not instantaneous.

*Mr. Carter*—It is popularly known as an explosion, is it not?

*Mr. Sargent*—Yes, it is usually called an explosion, yet if we put the engine on the center and explode the mixture, the pressure generated by the heat of combustion will fall below the compression pressure in less than two seconds. It is for that reason we ignite in advance of the dead center and maintain as high a piston speed as practicable.

*Mr. Mayer*—How many degrees before the dead center of the crank is reached, do you time the explosion?

*Mr. Sargent*—You cannot locate the point of ignition in degrees without knowing the conditions. It depends on many things,—piston speed, fuel, compression, shape of explosion chamber, temperature of cooling water, etc. The only way to determine it accurately is by the indicator.

*Mr. Schuchardt*—(M. W. S. E.)—Can you tell about the cost of the fuel for the gas compressing engine referred to?

..*Mr. Sargent*—It does not cost a great deal. Of couse, after the gas is piped several hundred miles, it is sold from 10 to 20 cents per thousand cu. ft. Steam generated in a gas fired boiler was formerly used for driving gas compressors.

*Prof. P. M. Chamberlain*—(M. W. S. E.)—What has been done in the line of gas producers, using bituminous coal?

*Mr. Sargent*—I believe some experimenting is being done at the Government Station in St. Louis, and that fair results are being obtained by the use of bituminous coal. I have not seen the reports, but I understand the results are quite satisfactory. I think there is a plant at Vincennes, Ind., in which the engine is run on producer gas made from bituminous coal. The tar is washed out by a centrifugal fan and the gas is used in an engine and for heating, and fair results are obtained. The plant is unquestionably a success.

*Mr. Loweth*—(M. W. S. E.)—Do you think the producer gas engine will supplant the small gasolene engine?

*Mr. Sargent*—I think it will be for stationary purposes, if fuel without tar is accessible and there is plenty of room for the producer. All suction producers require a fuel having no tar and I believe these producers which are made from 40 H. P. up, are giving fairly good satisfaction. If the load changes however, you get more air through the producer and the heat value of the gas changes.

*Prof. Chamberlain*—What are the largest installations of producer plants.

*Mr. Sargent*—There are producer plants in Steel Works which make producer gas for furnace heating, with a capacity of several thousand tons of coal in 24 hours, but of course the product is a dirty gas and could not be used in a gas engine without washing.

*Prof. Chamberlain*—Are there any used for power purposes?

*Mr. Sargent*—I do not now know of any very large ones for power purposes. There are some building and several contemplated, of the Mond type, in which the by-products are utilized; also the R. D. Wood & Co. have several of 2000 H. P. using anthracite coal, but I do not know of any very large producer plants for power purposes in this country using bituminous coal.

*Mr. Schuchardt*—How many B. T. U. are there in producer gas?

*Mr. Sargent*—The B. T. U. average in producer gas is about 125 per cu. ft. Illuminating gas contains 600 to 650 B. T. U. per cu. ft.

*Mr. Schuchardt*—They enrich the producer gas, do they not? I know that gas engine tests made at different times a day, differ.

*Mr. Sargent*—I have made natural gas tests in Chicago, getting about 1000 B. T. U. per cu. ft., and if it turned cold in the night, the next day I would get about 700 B. T. U. per cu. ft.

*Mr. Warder*—(M. W. S. E.)—Is the method of determining the B. T. U. of a gas a complicated one?

*Mr. Sargent*—It is a very simple process if you have a first class gas calorimeter. I have used both the Junker and Simmance-Abady instruments, and while the theory of each is all right, it is almost impossible to duplicate results with either, on account of the personal error which creeps in, when it is necessary to start and stop the determinations by the observation of the operator. As it is necessary to hold the inlet and outlet temperatures constant during a determination, it is desirable to make tests as short as possible, in which case the personal error of switching the outlet water, when a certain quantity of gas is burned is magnified. All imported instruments use the metric system and to eliminate the personal error previously mentioned, and that of transforming calories into B. T. U., the standard heat unit in the United States, I designed a calorimeter with Fahrenheit thermometers and an automatic device which switches the water from one receptacle to another for every tenth of a cubic foot of gas burned. The operator can make continuous tests with such an instrument and can get his B. T. U. direct

for every tenth of a foot of gas burned and a continuous record as long as desired.

*Mr. Warder*—Is it based on variation of temperature?

*Mr. Sargent*—The difference in temperature between the inlet and outlet water, times the pounds of water, times the cubic feet of gas, gives the B. T. U.

*Mr. Schuchardt*—Does gasoline give a higher M. E. P. than gas?

*Mr. Sargent*—That depends on the kind of gas. If you are using acetylene gas you can get more pressure than with gasolene. Natural gas is almost as good as gasolene.

*Mr. Mayer*—You mentioned that the building of large, vertical gas engines had not yet been developed. What is the reason for that?

*Mr. Sargent*—I do not know why the large, vertical gas engine has not been satisfactory. The largest vertical engine I have ever seen was an 800 H. P. and not a great success. Just what the troubles were, I do not know, except, of course, there is nothing to overcome the inertia of the reciprocating parts as in the tandem engine.

*Mr. DeWolfe*—(M. W. S. E.) These are serious troubles. I know of one installation which, within the last three months, has had at least seven crank shafts taken out.

*A Visitor*—Some ten or twelve years ago I had occasion to look into a certain plant, and the most frequent criticism I found was in the starting. The statement was made that one day they could start all right, and the next day they could not get it to go. I suppose those troubles have been perfected now, so that they do not occur.

*Mr. Sargent*—The starting of large gas engines with compressed air makes the operation as certain as the starting of steam engines if there is air under pressure available. The fact that people who do not know anything about engines, nor the handling of them, yet who run automobiles thousands of miles and get home safely, is the best evidence that the gas engine can be handled.

*Mr. W. L. Abbott*—(M. W. S. E.)—Mr. Sargent, I think, has put us all under great obligations tonight, for presenting this very valuable and interesting paper. I believe, however, that he and the Secretary conspired to have it presented without being published in advance so that the steam men might not have an opportunity to criticise his paper beforehand and check him up on some of his fairy stories. His last remark, about people who run gasoline machines thousands of miles and *always* get home, may be taken as an example of the accuracy of some of his other statements.

Mr. Sargent spoke of a gas engine installation—a large installation—which was running at a cost of about 1½ mills per B. H. P., and referred to that as being, in a way, a record. This, I take it, was by using anthracite culm and probably near the culm banks. The price of this culm was not stated, and I would like to have him state this, if he is able.

*Mr. Sargent*—The price was about 90 cents a ton, delivered, I think.

*Mr. Abbott*—It is possible, and it is being done every day in Chicago, to generate power by steam, using turbines, with Illinois slack coal, which bears a freight charge of 75 cents and costs, delivered in the city, $1.15 per ton, to generate power at a price as low as he mentions. This is with steam turbines in large units.

I think that the gas engine was born about ten years too late. As it is now, the steam turbine has obtained a foothold and the energies of the large builders in the country are being devoted more to the development of the turbine, as it promises better returns. Some of the pictures of gas engines, presented here tonight, appear to me real formidable, and, I think go a long way to explain why the gas engine has not made more rapid progress than it has.

After all is said, however, and admitting the increased simplicity of later designs, I consider that the real difficulty in the way of a more general use of gas engines lies in the fact that the engine itself is far ahead of the development of the gas producer, and until the gas producer is brought up to the state of perfection which the gas engine now has, the prime mover of the future will continue to be—the prime mover of the future.

# AVAILABLE POWER AND COST OF OPERATION OF A POWER STATION FOR WASTE GASES FROM A BLAST FURNACE PLANT.

H. Freyn, Cleveland, O.

*Presented December 20, 1905.*

The following calculation has been made assuming a new blast furnace plant of two 400-ton blast furnaces, situated in the immediate vicinity of a large city and having the ordinary facilities for water supply and for handling the raw and finished material. Assuming both furnaces in good operation and assuming a coke consumption of 1900 lbs. per ton of pig iron, there will be required $800 \times 1900 = 1,520,000$ lbs. of coke per day. This quantity of coke produces approximately 110,000,000 cu. ft. of gas in 24 hours, or, per ton of pig iron $110,000,000 \div 800 = 137,000$ cu. ft. of gas. The losses on the top of the furnaces may amount to approximately 5%, so that 130,000 cu. ft. of gas per ton of pig iron produced in 24 hours could be obtained. The average heat value of this blast furnace gas will be about 90 B.T.U. per cu. ft. The total quantity of gas available for the various purposes in this blast furnace plant amounts to $130,000 \times 800 = 104,000,000$ cu. ft. of gas per 24 hours or 4,350,000 cu. ft. per hour, having a total heat value of 391,500,000 B.T.U. Modern double acting gas engines of large capacity working on the four-cycle or Otto principle, built with the latest improvements and using high compression of mixture, consume less than 9,000 B.T.U. per B.H.P. per hour at full load capacity. The total quantity of gas produced by two blast furnaces of 400 tons capacity each, when used in gas engines for generating power, would operate at least $391,500,000 \div 9,000 = 43,500$ H-P per hour. If, therefore, all the gas generated by a blast furnace plant could be used for producing power, there would be available over 50 H-P per ton of pig iron produced per 24 hours.

This quantity of 4,350,000 cu. ft. of gas per hour will be divided for the various purposes of the blast furnace plant as follows: One part of the gas is used for heating the hot blast stoves, another for operating gas blowing engines and there is gas required for the auxiliary machinery, such as pumps, hoists, coke and ore handling machinery, power transmission, compressed air, pig-iron casting machinery, and for lighting the entire blast furnace plant; some of the gas is also necessary for operating gas engines

serving the gas cleaning plants and a certain percentage may be counted for losses in the piping, in the engines, the gas cleaning plant, etc. It will be seen that the total quantity of gas necessary for the operation of the blast furnace plant itself amounts to approximately 50% of the total quantity generated, leaving a little less than 50% available for useful work outside of the blast furnace plant itself.

### HOT BLAST STOVES.

It is generally figured that about 30% of the total quantity of gas generated by the blast furnace is required for heating the blast, although this quantity varies considerably according to the quality of the gas, the design and construction of the hot-blast stoves and according to the conditions of operation of the blast furnace plant in general.

For European blast furnace plants, the figure of 45% is found frequently in reports endeavoring to determine the available power from blast furnace plants, while in this country the gas necessary for the stoves is estimated in certain instances to be as low as 20% of the total quantity produced.

Edward A. Uehling, in his paper entitled, "The Blast Furnace as a Power Plant," determined by a very careful calculation that the quantity of gas necessary for heating the blast amounts to about 18% of the total quantity of gas. Other authors assume this quantity to be about 25% of the total gas for an average blast furnace plant in the United States.

### POWER FROM BLAST FURNACE GAS.

Assuming 30%, we are certainly on the safe side and so much more so, since in a new blast furnace plant all the gas leaving the top of the blast furnaces would be subjected to a cleaning process, thus removing the bulk of the dust carried along by the gas. The question of cleaning the blast furnace gas which is required for the hot blast stoves and the boilers in a blast furnace plant, has not as yet received as much attention in this country, as it has in Europe, where most of the large blast furnace plants have been equipped, during the last two or three years, with extensive gas washing plants, cleaning practically every particle of gas produced by the furnaces. Very exhaustive tests as to the advantage of cleaning the gas for stoves and boilers have been made by Mr. Emil Hiertz, Supt. of the blast furnaces of the John Cockerill Company, of Seraing, Belgium.

As far as gas consumption of the hot blast stoves is concerned he found that by using clean gas the temperature of the stoves could be increased at least 200° F., and it will be seen at a glance

that this fact tends to decrease the quantity of gas necessary for obtaining a certain temperature in the hot blast stoves, so that in the future the percentage of gas to go into the stoves will be materially decreased.

Assuming the figure of 30%, the total quantity of gas necessary for heating the blast will be $4{,}350{,}000 \times 0.30 = 1{,}305{,}000$ cu. ft. per hour.

GAS BLOWING ENGINES.

A new blast furnace plant will in the future be equipped with just one steam blowing engine for starting the blast furnaces, (unless gas producers should be installed) while the rest of the blowing engines will be operated by gas engines. The quantity of blast required will be 90 cu. ft. per minute per ton of pig iron produced, or for 800 tons, $800 \times 90 = 72{,}000$ cu. ft. of blast per minute.

Assuming that all the necessary blast be furnished by gas blowing engines, the latter will normally have to compress the blast to about 15 to 18 lbs. per square inch, but as it will be occasionally necessary to blow against a pressure of 30 lbs. per square inch, the gas blowing engines must be large enough to do this work. Figuring on a maximum pressure of about 30 lbs. per sq. in. the work necessary to compress 100 cu. ft. of air against this pressure for adiabatic compression will amount to 8.65 H-P theoretical, or nearly 10 B.H.P. in the gas engine. As 72,000 cu. ft. per minute have to be compressed, $720 \times 10$ or 7,200 B.H.P. in gas engines must be provided for. The engines would, under these conditions, operate under full load. The heat consumption, as stated before, will be less than 9,000 B.T.U. per B.H.P. per hour, (Actual tests on a double acting tandem Cockerill gas engine show a heat consumption of 8,880 B.T.U. per B.H.P. per hour) but assuming 9,000 B.T.U. per B.H.P. per hour, one B.H.P. hour will require $9{,}000 \div 90 = 100$ cu ft. of gas, and 7,200 B.H.P. in blowing engines will therefore require 720,000 cu. ft. of gas per hour.

As previously mentioned, under ordinary conditions, the gas blowing engines will have to blow against only 15 to 18 lbs. pressure. Taking the lower figure of 15 lbs. per sq. in. there will be required 5.125 H-P per 100 cu. ft. of blast theoretically, or approximately 6. B.H.P. per 100 cu. ft. in the blowing engines. For the total quantity of blast of 72,000 cu. ft. per minute, there will be required $720 \times 6 = 4{,}320$ B.H.P.

The gas blowing engines are supposed to be ample in size to give a maximum of 7,200 B.H.P. They would therefore operate normally on $(4{,}320 \times 100) \div 7{,}200 = 60\%$ of their full load capacity.

The above mentioned test, made on a 1,500 H-P double-acting tandem gas engine built by the John Cockerill Company, of Sera-

ing, Belgium, shows a heat consumption of 10,800 B.T.U. per B.H.P. per hour for the engine running at two-thirds of its full load capacity. According to a curve plotted from the above tests, the engine running at 60% load would show a heat consumption of about 11100 B.T.U. per B.H.P. per hour. Let it be even 11500 B.T.U. per B.H.P. per hour, at 60% load of the engine, then the amount of gas required would be $11500 \div 90 = 128$ cu. ft. per B.H.P. per hour, making the total requirements for blowing engines equal to $4300 \times 128 = 550000$ cu. ft. per hour.

This quantity is less than the quantity required at full load by about 170,000 cu. ft. per hour. In other words, 720,000 cu. ft. of gas for the purpose of gas blowing engine is the *maximum* that would ever be required.

### AUXILIARY MACHINERY.

The power necessary for lighting the plant, for pumps, hoists, and all the necessary machinery for operating the blast furnace plant, could be assumed to be about 1.5 B.H.P. per ton of pig iron produced per day. This figure will take into account all the modern machinery with which an up-to-date blast furnace plant is equipped, and is certainly very conservative, as other authorities estimate the auxiliary power to be far less.

A. Ernst gives the figure of 1 H-P per ton of pig iron produced, Edward Uehling gives about 1.04 H-P, W. Oswald, of Coblenz, gives 1 H-P, and the John Cockerill Company about 1.05 H-P per ton of pig iron produced. At the rate of 1.5 H-P per ton of pig iron for auxiliary machinery, the total requirements for the blast furnace plant of 800 tons will amount to $800 \times 1.5 = 1200$ B.H.P. If this power be generated by gas engines and assuming a gas consumption of 100 cu. ft. per B.H.P. hour, the total quantity of gas to be deducted for auxiliary power purposes will be $1200 \times 100 = 120,000$ cu. ft.

### GAS CLEANING.

It has been already indicated that a modern blast furnace plant will be equipped, in the future, with extensive gas cleaning apparatus to cleanse all the gas produced by the furnaces. Aside from the advantage of obtaining a higher temperature in the hot-blast stoves, thus decreasing the quantity of gas necessary for heating the blast and eventually decreasing the coke consumption per ton of pig iron produced, there is a decided advantage in using clean gas for heating the stoves, as the latter do not require to be cleaned as often. This would mean a considerable saving in labor actually expended in the blast furnace plants for removing the dust which accumulates in a very short time in the flues of the hot blast stoves.

It would even be possible by using clean gas to do away entirely with the spare hot blast stoves, thus saving considerably on the first cost of the installation.

As the gas-washing apparatus delivers the gas under a pressure of from three to four inches of water, the size of the conduits for conveying the gas could be decreased for new blast furnace plants, which again would mean a reduction in the first cost.

That the clean blast furnace gas is by far more advantageous in its use, than dirty gas, is shown by an experience had at the blast furnace plant at Seraing. After cleaning a boiler and putting same into commission again, it required with dirty gas 3 hours time to get up the steam pressure, while by using clean gas, this time could be reduced to 1½ hours. It is a well known fact that clean gas burns far better than gas containing considerable quantities of very fine dust.

In Europe, the centrifugal gas cleaning apparatus invented by Mr. Edward Theisen is used almost exclusively for gas cleaning plants. This apparatus requires for a given amount of gas, less power, less water and less attendance and is giving far better results than the so-called hydraulic fans which were used six years ago.

In the blast furnace plant of the John Cockerill Company for instance, all the gas produced by two blast furnaces is subjected to a thorough washing in Theisen gas washers of the largest capacity and the Cockerill Company intend in the near future to clean in this way all the gas produced by seven furnaces. After leaving the first installation of Theisen apparatuses, the gas is divided in two branches, one part going directly to the hot blast stoves and boilers, while the other branch leads to a second series of Theisen gas washers where the gas is subjected to a second washing and scrubbing process, thus making it perfectly clean and suitable for operating gas engines.

According to the experience as indicated by European practice for cleaning the gas generated by the blast furnaces, it may be assumed that all the gas for our 800 ton blast furnace plant is to be cleansed in Theisen gas washers of large capacity, to such an extent as not to contain more than about 0.5 grams of dust per cubic meter. The part of the gas for operating gas engines will be subjected to a further cleaning in Theisen gas washers, which will bring down the amount of dust contained in the gas to 0.03 grams per cubic meter (corresponding to 0.0131 grains per cubic foot) or even to a less amount. Experience shows that engines using clean gas are able to run six months and more continuously day and night without the necessity of cleaning them internally.

In order to clean 10,000 cu. ft. of gas per hour to such a degree of cleanliness as to be suitable for the hot blast stoves, the Theisen gas washers require about 1.25 H-P (actual test shows 1.15 H-P). The power necessary for cleaning the whole quantity of 4,350,000 cu. ft. of gas per hour will therefore amount to $435\times1.25=550$ B.H.P.

As stated before, 30% of this clean gas goes to the stoves, leaving 70% to pass through the second series of Theisen gas washers. Gas cleaned for gas engine purposes in Theisen gas washers requires about 1.5 B.H.P. for each 10,000 cu. ft. of gas per hour, (actual tests show only 1.3 B.H.P.)

The power required for the second series of gas washers will therefore amount to $0.7\times435\times1.5=460$ B.H.P., and the total power required for gas washing purposes will be 1010 B.H.P. Gas dynamos will generate the necessary electric current for operating the electric motors of the gas washers.

With a combined efficiency of 85%, the required capacity of the gas engine will be about 1200 B.H.P. and at the rate of 100 cu. ft. of gas per B.H.P. per hour, there will be required for gas cleaning purposes another $1200\times100=120,000$ cu. ft of gas per hour.

Figuring back on the tonnage of pig iron, it will be seen that the power required for gas cleaning purposes amounts to about 1.5 H-P per ton of pig iron produced in 24 hours.

This figure coincides very nicely with the figure given by W. Oswald, of Coblenz, which is 1.6 H-P per ton of pig iron produced per 24 hours.

### LOSSES.

In the piping for the engines, in the gas engines themselves and in the gas cleaning plant, about 5% of the gas required might be lost by leakage, etc. The total loss would therefore amount to $0.05\times960,000=48,000$ cu. ft.

After deducting the quantities of gas necessary for the various purposes of the blast furnace plant there remains available for other purposes, in round figures 2,000,000 cu. ft. of gas per hour as shown by the following summary. (See opposite page.)

This quantity of gas at the rate of 100 cu. ft. per B.H.P. per hour would provide for 20,000 B.H.P.

Per one ton of pig iron produced per 24 hours, there will therefore be available for sale or for other useful work 25 H-P. As found previously, the total quantity of gas generated by two 400-ton furnaces represents over 50 B.H.P. per ton of pig iron produced per 24 hours.

Generally speaking, 50% of the power represented in the gas produced by a blast furnace plant is available for sale.

The blast furnaces are subject to certain unavoidable irregularities on account of which a "coefficient of safety" must be introduced in the calculation for determining the available power from a blast furnace of a given capacity. This coefficient is of course

— TABLE No. 1. —

— SUMMARY —

| | | |
|---|---|---|
| TOTAL AMT. GAS PRODUCED PER HOUR | | 4,350,000 CU. FT. |
| AMT. TO BE DEDUCTED | | |
| FOR HOT BLAST STOVES | 1,305,000 CU. FT. | |
| " GAS BLOWING ENGINES | 720,000 " " | |
| " OPERATING AUXILIARY MACHINERY | 120,000 " " | |
| " " GAS CLEANING PLANTS | 120,000 " " | |
| " LOSSES IN PIPING, ENGINES, ETC. | 48,000 " " | |
| TOTAL | 2,313,000 " " | 2,313,000 CU. FT. |
| AMT. AVAILABLE FOR OTHER PURPOSES OUTSIDE BLAST FURNACE PLANT REQ'MTS PER HR. | | 2,037,000 " " |
| IN ROUND FIGURES PER HOUR | | 2,000,000 CU. FT. |

extremely variable and depends largely upon the pig iron market (which might require a banking of the furnaces), upon the operation of the furnaces, the quality and supply of ore, coke, etc. It is very difficult to foretell how much of the total theoretical available horse power from two 400-ton furnaces could actually be realized, especially when the electric power generated by using this gas in gas engines is to be sold to outside consumers to whom the delivery of a certain amount of power naturally *must* be guaranteed, perhaps under a heavy penalty. This irregularity in the operation of a blast furnace will have a very great influence on the production of gas, affecting the quantity as well as the quality.

With two blast furnaces only it would be perfectly safe to figure on the available horse-power from the gas of one furnace only, assuming this coefficient to be 0.5.

Following the above outlined order of ideas a blast furnace plant of only two 400-ton furnaces should be equipped in the beginning with a power station of only limited capacity corresponding to the available power from only one furnace, installing later on additional units, if the conditions and operations of the furnace plant would be such as to safely permit the generation of additional electrical power.

The following calculation has been made on the assumption that an electric power plant of about 10,000 B.H.P. be installed first. The size of unit best suited for this power plant would be an engine of about 1500 B.H.P. capacity. Seven gas engines of 1500 B.H.P. rated capacity would develop 10,500 B.H.P.

In order to meet emergencies an eighth engine as a standby or spare unit should be installed, so that the power plant in the beginning would consist of eight units as above.

Generators of 800 K.W. would, at the rated load of the gas engines of 1500 B.H.P., develop about 1000 K.W. or 800 K.W. plus 25% overload. At maximum load of the gas engines of 1650 B.H.P., the generators would carry 1120 K.W. each, or 800 K.W. plus 40% overload.

It will be seen that 800 K.W. generators would perfectly fulfill the requirements, as they easily stand an overload of 25% for 24 hours and an overload of 40% for short periods.

## COST OF ELECTRIC POWER STATION OF 10,000 B.H.P. CAPACITY.

The complete equipment of the power plant would consist of: Eight (8) double acting tandem Wellman-Cockerill Gas Engines, cylinders, 38 in. diameter, by 54 in. stroke, at 85 R.P.M., with a rated load of 1750 I.H.P., or 1500 B.H.P. each, to be direct connected to

A. C. Generators, 800 K.W. 3-phase, 25-cycle, 6600-volt, and including exciters, switchboard and wiring.

Gas cleaning plant for power station only;

Complete piping;

Air compressor outfit;

Buildings, foundations and traveling crane.

## COST OF INSTALLATION OF POWER PLANT.

— TABLE No. 2 —

— COST OF INSTALLATION OF POWER PLANT. —

— CAPITAL ACCOUNT —

| ITEM | WEIGHT | COST |
|---|---|---|
| GAS CLEANING PLANT | 250,000 LBS. | $33,500 |
| BUILDING & FOUNDATION FOR SAME | | 6,500 |
| RING GAS MAIN | 100,000 " | 6,000 |
| BUILDING FOR 8 GAS DYNAMOS | | 45,000 |
| FOUNDATION FOR ENGINES | | 26,000 |
| TRAVELING CRANE | 120,000 " | 8,500 |
| 8 GAS ENGINES | 4,000,000 " | 424,000 |
| COMPLETE PIPING | 470,000 " | 24,000 |
| AIR COMPRESSOR OUTFIT | 40,000 " | 5,000 |
| COMPLETE ELECTRICAL EQUIPMENT | 670,000 " | 162,500 |
| TOTAL WEIGHT OF MACHINERY | 5,650,000 LBS. | |
| TOTAL COST OF INSTALLATION | | $741,000 |
| COST OF INSTALLATION PER BHP (TOTAL CAPACITY 12000 B.H.P.) | | 61.60 |
| COST OF INSTALLATION PER KW TOTAL CAPACITY 8300 K.W. | | $89.50 |

COMMENTS ON TABLE NO. 2.

GAS CLEANING PLANT.

The part of the gas washing plant chargeable to the power house has to clean a maximum of $12,000 \times 100 = 1,200,000$ cu. ft. of gas per hour, or 20,000 cu. ft. per minute, provided that all eight gas engines are in operation under full load. This quantity of 20,000 cu. ft. of gas per minute, which has previously been cleaned with the bulk of the gas of the furnaces, can be cleaned by a gas washing plant consisting of four Theisen gas washers No. 3, capable of cleaning an average of 6000 cu. ft. of gas per minute each. A spare Theisen apparatus is not necessary, as in case of a shut down of one washer for cleaning or repairs, the three remaining washers will easily take care of the total quantity of gas.

Each Theisen apparatus would be directly coupled to a 70 B.H.P. electric motor running at a speed of about 450 R.P.M.

Between the gas main and the Theisen apparatus, there should be inserted a pressure regulator which automatically shuts off the entrance of gas to the cleaning plant in case of a lack of gas, thus avoiding a vacuum in the main gas conduit, and consequently preventing the entrance of air into the latter, which might produce dangerous explosive mixtures in the pipe line. The gas pressure regulator and the four Theisen gas washers could be arranged in such a way that by the simple manoeuvering of a few valves, the gas can be "by-passed" at the pressure regulator or each Theisen apparatus, thus permitting the cleaning or repairs of the latter without interfering in the least with the operation of the power plant.

Each Theisen apparatus would deliver the clean gas into the water separator situated in front of the gas washer. These separators take out the water from the gas and deliver clean, cool and dry gas into a collecting pipe, which, in turn is connected to the gas main situated around the engines.

All piping for connections of the various items of the cleaning plant as well as all water piping is included in the price.

BUILDING AND FOUNDATION FOR GAS CLEANING PLANT.

A light steel frame building with brick walls and solid roof is sufficient to shelter the Theisen gas washers, their motors and the water separators. This building would be about 100 ft. long and 30 ft. wide, and should be provided with a traveling crane of 5-ton capacity and 30 ft. span.

GAS MAIN.

Surrounding the engines and in the building there should be installed a ring gas main of about 4 ft. diameter, from which the engines take their supply of gas. This ring conduit avoids all pos-

sible interference between the gas streams leading to the various engines and secures a uniform supply of gas.

No connection between this gas main and the gas cleaning plant has been considered in this estimate, as it depends upon the local conditions and arrangements.

### BUILDING FOR GAS ENGINES.

The building for the gas engines would be about 85 ft. wide and 250 ft. long. It should be a steel structure with brick walls and slate roof, with hardwood floor and provided with runways for the electric traveling crane.

### FOUNDATION FOR GAS ENGINES.

Each 1500 H-P gas engine requires a volume of concrete of about 10,000 cu. ft. The price as given in Table 2, includes foundations for eight engines and all the iron work, such as foundation bolt washers, girders, supports for piping, etc.

### TRAVELING CRANE.

An electric traveling crane of about 25 tons capacity and about 85 ft. span with main and auxiliary trolley would be required.

### GAS ENGINES.

The price as given for the gas engines would include all the necessary auxiliary apparatus, such as electrically driven barring over devices, pumps operated by the main shaft of each engine for circulation of water under pressure through pistons and piston rods, complete piping, etc. It would also include governors having special hand-operated regulating devices for synchronizing the engines, and fly-wheels of sufficient size, which, together with the revolving element of the generators, would assure such a close regulation as to synchronize and run the generators in parallel without difficulty.

The regulation of the engine should be performed by admitting a variable quantity of a constant mixture which follows a certain volume of air, so that the compression is constant and the valve gear mechanism should be as simple and noiseless as possible.

Modern double-acting tandem gas engines will perform one B.H.P. on:

At full load, 9,000 B.T.U. or 100 cu. ft. of gas.

At ¾ load, 10,000 B.T.U. or 112 cu. ft. of gas.

At ½ load, 12,600 B.T.U. or 140 cu. ft. of gas.

### PIPING.

The price of complete piping, as given in Table No. 2, covers all the piping for gas, air, exhaust, compressed air and water inside of

the engine building and connections to the gas main and also includes two exhaust mufflers with stacks and compressed air tank on each engine.

### AIR COMPRESSOR OUTFIT.

The air compressor outfit would consist of two electrically driven 2-stage air compressors having a capacity of 150 cu. ft. of free air per minute each, compressing against 150 lbs. to the square inch. A main compressed-air reservoir with safety valve and gauges is included in the price.

The capacity of each air compressor outfit would be ample to permit the simultaneous starting of two engines.

### ELECTRICAL EQUIPMENT.

The electrical equipment would comprise 8— 800 K.W.—A.C. generators, two "exciter units," driven independently, the switchboard and the complete wiring between generators and switchboard.

## OPERATING COST OF POWER PLANT.

The operating cost of the power plant consists of:

(a) Fixed charges; comprising the interest of the money invested in the plant, depreciation and maintenance of various items, insurance and taxes.

(b) The cost of water consumed for washing and cooling purposes.

(c) Cost of oil and grease.

(d) Expenditures for repairs on gas cleaning plant, engines, piping and electrical equipment.

(e) Expenditure for wages and salaries.

(f) Cost of fuel.

The computation of the operating cost of power plant has been made for three different assumptions:

First, the power plant running at full load capacity; output 10,500 B.H.P. per hour, = 91,980,000 B.H.P. hours per year; or 7,250 K.W. per hour, = 63,510,000 K.W. hours per year;

Second, power plant running at ¾ load; output 8,000 B.H.P. per hour, = 70,080,000 B.H.P. hours per year; or 5,500 K.W. per hour. = 48,180,000 K.W. hours per year;

Third, power plant running at ½ load capacity; output 5,000 B.H.P. per hour, = 43,800,000 B.H.P. hours per year; or 3,600 K.W. per hour, = 31,536,000 K.W. hours.

One year = 365 days, one day = 24 hours.

## TABLE No. 3

## FIXED CHARGES

| ITEM | COST $ | INTEREST % | DEPRECIATION % | INSURANCE % | TOTAL % | LIFE OF PLANT YEARS | TOTAL PER ANNUM $ |
|---|---|---|---|---|---|---|---|
| GAS CLEANING PLANT | 33500 | 5 | 10 | 1 | 16 | 8.31 | 5360 |
| BUILDING & FOUNDATIONS | 6500 | 5 | 4 | 1 | 10 | 16.62 | 650 |
| RING GAS MAIN | 6000 | 5 | 5 | 1 | 11 | 14.21 | 660 |
| BUILDINGS FOR 8 GAS DYNAMOS | 45000 | 5 | 4 | 1 | 10 | 16.62 | 4500 |
| FOUNDATIONS FOR ENGINES | 26000 | 5 | 4 | 1 | 10 | 16.62 | 2600 |
| TRAVELING CRANE | 8500 | 5 | 5 | 1 | 11 | 14.21 | 930 |
| GAS ENGINES | 424000 | 5 | 8 | 1 | 14 | 9.95 | 59360 |
| COMPLETE PIPING | 24000 | 5 | 5 | 1 | 11 | 14.21 | 2640 |
| AIR COMPRESSOR OUTFIT | 5000 | 5 | 5 | 1 | 11 | 14.21 | 550 |
| COMPLETE ELECTRICAL EQUIPMENT | 162500 | 5 | 8 | 1 | 14 | 9.95 | 22750 |
| TOTALS | 741000 | 5 | | | 13.5 | | 100000 |
| FIXED CHARGES PER KW HOUR AT FULL LOAD | | | | | | | 0.1575¢ |
| " " " " " " 3/4 LOAD | | | | | | | 0.2076¢ |
| " " " " " " 1/2 LOAD | | | | | | | 0.3171¢ |

## (*b*) WATER.

### AT FULL LOAD CAPACITY OF THE PLANT.

#### GAS WASHING PLANT.

For cleaning 1,000 cu. ft. of gas per minute, the Theisen gas cleaning apparatus requires a maximum of 12 gallons of water. The part of the gas cleaning plant chargeable to the power house has to clean a maximum of 12,000×100=1,200,000 cu. ft. of gas per hour, or 20,000 cu. ft. per minute, requiring 240 gallons per minute, or 14,400 gallons per hour, making per day 345,600 gallons.

#### GAS ENGINES.

At full load, the gas engine will consume about 8.5 gallons of water per B.H.P. per hour. At 10,500 B.H.P. rated capacity of power plant, the requirements of cooling water will be 89,250 gallons per hour, or 2,142,000 gallons per day, or say per day, 2,154,-400 gallons.

Total quantity of water per day, 2,500,000 gallons.

The blast furnace plant being supposed to be located near a stream of water, the cooling water could be provided from the pumping station of the plant at a very low cost of pumping, say at 2c per 1,000 gals. At this rate, the total expenditure for water per day would be $50.00.

Water per K.W. hour at full load 0.02874c.

### AT ¾ LOAD CAPACITY OF THE PLANT.

#### GAS WASHING PLANT.

The gas washing plant will require at ¾ load about 14 gallons of water per 1,000 cu. ft. of gas per minute.

As previously stated, the heat consumption of the gas engines running at ¾ load will amount to 10,000 B.T.U. per B.H.P. per hour, or, in other words, one B.H.P. hour will require 112 cu. ft. of gas. The output of the power plant being 8,000 B.H.P. at ¾ load, the total gas consumption per hour will amount to 896,000 cu. ft. or 14,933, say 15,000 cu. ft. of gas per minute.

The quantity of washing water for cleaning this quantity of gas will be 14×15.0=210 gallons per minute, or 12,600 gallons per hour, or per day, 302,400 gallons.

#### GAS ENGINES.

The consumption of cooling water at ¾ load will amount to 10.5 gallons per B.H.P. per hour; therefore 8,000 B.H.P. will require 84,000 gallons per hour, or per day 2,016,000 gallons.

Total quantity of water per day, 2,318,400 gallons, say in round figures, 2,320,000 gallons.

At the rate of 2c per 1,000 gallons, the total expenditure for water for cooling and washing purposes will amount to $46.40 per day.

Water per K. W. hour at ¾ load, 0.03514c.

AT ½ LOAD CAPACITY OF THE PLANT.

GAS WASHING PLANT.

At ½ load the consumption of washing water for the Theisen gas washers will amount to 16 gallons per 1,000 cu. ft. of gas cleaned per minute. The heat consumption of the gas engines as previously stated will be 12,600 B.T.U. per B.H.P. hour, or one B.H.P. hour will require 140 cu. ft. of gas.

The total quantity or gas consumed will be 700,000 cu. ft. per hour or about 11,700 cu. ft. per minute. The amount of washing water will therefore be 187.2 gallons per minute or 11,232 gallons per hour, making per day 269,568, say 270,000 gallons.

GAS ENGINES.

The consumption of cooling water at ½ load amounts to 13 gallons per B.H.P. hour, requiring $13 \times 5{,}000 = 65{,}000$ gallons per hour, or per day, 1,560,000 gallons.

Total quantity of water for power plant per day, 1,830,000 gallons.

At the rate of 2c per 1,000 gallons, the total expenditure for water per day will amount to $36.60.

Water per K.W. hour at ½ load, 0.04236c.

## (c) OIL AND GREASE.

AT FULL LOAD CAPACITY OF THE PLANT.

According to actual performance of large gas engine power plants, the plant of 10,500 B.H.P. in operation, including electrical equipment and auxiliary machinery, such as Theisen apparatuses, air compressors, etc., will not consume more than 2 grams of lubricants per B. H. P. hour, 1.2 grams of which will be cylinder oil at 35c per gallon, and 0.8 grams of which will be engine oil at 20c per gallon.

The total expenditure per year will, therefore, amount to $15,645.

Oil and Grease per K. W. hour at full load, 0.02460c.

AT ¾ LOAD CAPACITY OF THE PLANT.

The quantity of lubricants required for the power plant, when running at ¾ load, will not be very much less than at full load capacity; in any event it might be assumed that the total expenditure will be about 10% less per year than at full load capacity of the plant. The cost of lubrication of the power plant will therefore amount to $14,080 per year.

Oil and Grease per K.W. hour at ¾ load, 0.02922c.

AT ½ LOAD CAPACITY OF THE PLANT.

About 15% might be deducted from the cost of lubrication for the power plant when running at full load capacity, as at an almost constant load factor of 0.5 several engines would be shut down.

The total expenditure per annum for lubrication of power plant running at ½ load capacity would therefore amount to $13,300.

Oil and Grease per K. W. hour at ½ load, 0.04219c.

## (d) REPAIRS ON MACHINERY.

Although the item depreciation and maintenance of the gas power plant covers certain repairs on the machinery, and as small repairs would have to be made by the operating personnel inside of their regular working hours, it is usual to figure on a separate item for repairs on machinery, providing for accidents which might require the replacing or repairing of certain parts of the machinery. Experience with large power plants in Europe indicates that repairs of this kind do not exceed about 2½% per year of the purchase price of the gas engines and generators. For the gas cleaning plant, 7% per year of the purchasing price may be assumed, while for the air compressor 5%, and for piping and crane 2% per year of the respective purchasing prices, will cover necessary repairs on these items.

AT FULL LOAD CAPACITY OF THE PLANT.

The total expenditure for repairs on the power plant equipment will thus amount to about $18,000 per year.

Repairs per KW. hour at full load, 0.02834c.

AT ¾ LOAD CAPACITY OF THE PLANT.

As the machinery is less strained when running at an average of ¾ load per year, a certain percentage of the expenditure for repairs per year for full load capacity of power plant might be deducted. Assuming that this reduction may amount to about 10%, the total cost of repairs per year will amount to about $16,800.

Repairs per K.W. hour at ¾ load, 0.03362c.

AT ½ LOAD CAPACITY OF THE PLANT.

A deduction of about 15% of cost of repairs at full load capacity of power plant may properly be applied, so that the expenditure per annum for the plant running at ½ load capacity will amount to approximately $15,300.

Repairs per K.W. hour at ½ load capacity, 0.04852c.

## (e) WAGES AND SALARIES.

### AT FULL LOAD CAPACITY OF THE POWER PLANT.

The power plant when running at its full load capacity will require the following attendants:

| | Per Year. |
|---|---|
| 1 Chief Engineer | $ 3,000 |
| 1 Assistant | 1,800 |
| 8 Machinists at 30c per hour, for gas engines only | 10,513 |
| 10 Helpers at 21c per hour | 9,198 |
| 2 Machinists at 25c per hour, for gas cleaning plant and compressors | 2,190 |
| 4 Dynamo tenders at 22.5c per hour | 3,942 |
| 4 Switchboard tenders at 20c per hour | 3,504 |
| 1 Bookkeeper and clerk | 1,200 |
| Total per year | $35,346 |

Say in round figures, $35,350 per year.

Wages and Salaries per K.W. hour, at full load, 0.05566c.

### AT ¾ LOAD CAPACITY OF THE POWER PLANT.

Not much money could be saved in wages and salaries for the power plant when the latter is running at ¾ load; possibly one dynamo tender and one switchboard tender could be dispensed with, so that the total expenditure for wages and salaries per annum would amount to $33,500.

Wages and Salaries per K.W. hour at ¾ load, 0.06953c.

### AT ½ LOAD CAPACITY OF THE POWER PLANT.

At ½ the capacity of the power plant, one dynamo tender and one switchboard tender, also two helpers, could be dispensed with, so that the total expenditure for wages and salaries per year would amount to $31,600.

Wages and Salaries per K.W. hour at ½ load, 0.10020c.

## (f) FUEL.

### AT FULL LOAD CAPACITY OF THE POWER PLANT.

It is generally assumed in computations determining the operating cost of a blast furnace gas power plant, that the blast furnace gas has no value, so that the item "Cost of Fuel" is generally omitted in such calculations. This, perhaps, might have been permissible formerly when the blast furnace gas was used in the condition in which it left the standard dry dust catchers containing immense quantities of dust, thus restricting considerably the field of utilization of these gases.

In modern blast furnace plants, all the gas will be subjected to a thorough cleaning process, which entails certain expenditures for installation, power, maintenance, and attendance for the gas cleaning plant. It is, therefore, only fair to appraise the blast furnace gas which is used for operating gas engines. To my knowledge the late L. Ehrhardt-Schleifmuehle was the originator of the idea of appraising blast furnace gas.

He compares the value of blast furnace gas with the actual cost of steam in proportion to the heat value, reasoning, that the gas in the gas engine cylinders is utilized just as directly as the steam is in the cylinders of a steam engine.

Let us assume that the price of coal delivered into bins at the plant be $2.75 per ton, that the coal have a heat value of 13,000 B.T.U. per pound, and, further, that steam of 150 lbs. boiler pressure or about 165 lbs. absolute pressure be raised by burning this coal under boilers. One pound of steam will then contain 1,225 B.T.U. from O° F. Assuming feed water at 70°, there would be required 1,155 B.T.U. to generate 1 lb. of steam of 150 lbs. boiler pressure. In a boiler plant having 65% efficiency, 1,000 lbs. of coal could raise $(0.65\times1{,}000\times13{,}000)\div1{,}155=7{,}300$ lbs. of steam. The value of 1,000 lbs. of steam would be $2.75\div(2\times7.3)=\$0.188$, or 18.8c. To this must be added for labor and maintenance approximately 1c per 1,000 lbs. of steam, making the total value of 1,000 lbs. = 19.8c. 1,000 cu. ft. of blast furnace gas have a heat value of $1{,}000\times90=90{,}000$ B.T.U., and are equivalent to $(0.65\times90{,}000)\div1{,}155=51$ lbs. of steam, which in turn are worth $51\div1{,}000\times19.8=1$c.

The value of 1,000 cu. ft. of blast furnace gas would, therefore, be 1c.

Another way of determining the value of blast furnace gas would be to compare it with natural gas, 1,000 cu. ft. of natural gas having a heat value of 900 B.T.U. per cu. ft. represent 900,000 B.T.U. At a price of 10c per 1000 cu. ft. for natural gas, the value of 1,000 cu. ft. of blast furnace gas would be $90{,}000\div900{,}000\times10=1$c. 1,000 cu. ft. of blast furnace gas will at the rate of 100 cu. ft. per B.H.P. per hour develop at full load, $1{,}000\div100=10$ B.H.P. hours. The value of the blast furnace gas consumed per B.H.P. hour will therefore be 0.1c. Fuel per K.W. hour at full load, 0.1448c.

### AT ¾ LOAD CAPACITY OF THE POWER PLANT.

The gas consumption of the power plant when running at ¾ load amounts to 112 cu. ft. per B.H.P. per hour; the value of which is 0.112c. Fuel per K.W. hour at ¾ load capacity, 0.1629c.

AT ½ LOAD CAPACITY OF THE POWER PLANT.

The gas consumption under these conditions amounts to 140 cu. ft. per B.H.P. hour, the value of which is 0.14c. Fuel per K.W. hour at ½ load capacity, 0.1944c.

With coal at $3.25 per ton, 1,000 lbs. of steam at 150 lbs. boiler pressure would be worth 23c. The value of 1,000 cu. ft. of blast furnace gas would then be $(0.65 \times 90{,}000 \times 23) \div (1{,}155 \times 1{,}000) =$ 1.173c.

Compared with natural gas of 900 B.T.U. per cu. ft., the value of the blast furnace gas would correspond to a price of 11.73c per 1,000 cu. ft. of natural gas.

The following tables Nos. 4, 5 and 6 give a summary of the cost of operation for each item for full load, three-quarter load and one-half load capacity of the power plant, and the accompanying diagram shows curves plotted from these tables.

CONCLUSIONS.

From the above computations, it will be seen that a power plant of about 10,500 B.H.P. capacity complete in every detail and installed in connection with a blast furnace plant, would be capable, when running at full load capacity, of producing 1 B.H.P. per year at the low cost of $17.88, no value being placed on the blast furnace gas.

The enormous saving as compared with the production of power in a steam engine plant is still more striking, when the cost of generation of electric current is considered. According to the above tables, one K.W. hour at full load capacity of the plant could be produced at 2.95 mills, which is away below the best figure ever reached with a steam engine power plant. Even under worse conditions, that is, when the power plant is running on an average of only 50% of its total capacity, the cost of generation of one K.W. hour is but 5.50 mills.

It is evident that an eventual increase in the capacity of the power plant would still tend to reduce the cost of the generation of power per unit, as certain expenditures for the power plant of 10,500 B.H.P. would remain unchanged for additional power units.

Computations of this character are sometimes considered as being "theoretical," as they naturally can only be made by making certain assumptions. That such figures have some practical value, inasmuch as they permit the clear understanding of the results of practical experience, accounting for the make-up of these figures, will be appreciated by studying the following diagrams, which give actual figures obtained in the works of the John Cockerill Company.

The John Cockerill Company have in operation at present seven

## —TABLE No. 4.—

### —OPERATING COST OF POWER PLANT—

### —FULL LOAD—

| | ITEM | PER KW YEAR $ | PER KW HOUR ¢ | PER BHP YEAR $ | PER BHP HOUR ¢ |
|---|---|---|---|---|---|
| a | FIXED CHARGES | 13.793 | 0.15745 | 9.524 | 0.10871 |
| b | WATER | 2.518 | 0.02874 | 1.783 | 0.01984 |
| c | OIL & GREASE | 2.155 | 0.02460 | 1.490 | 0.01700 |
| d | REPAIRS | 2.483 | 0.02834 | 1.714 | 0.01957 |
| e | WAGES & SALARIES | 4.876 | 0.05566 | 3.366 | 0.03843 |
| | TOTAL WITHOUT VALUE OF B.F. GAS | 25.825 | 0.29479 | 17.877 | 0.20355 |
| | IN ROUND FIGURES | $25.83 | 0.295¢ | $17.88 | 0.204¢ |
| f | FUEL EQUIVALENT TO COAL @ $2.75 | 12.69 | 0.145 | 8.76 | 0.100 |
| | TOTAL | $38.52 | 0.440¢ | $26.64 | 0.304¢ |
| f | FUEL EQUIVALENT TO COAL @ $3.25 | 14.89 | 0.170 | 10.28 | 0.117 |
| | TOTAL | $40.72 | 0.465¢ | $28.16 | 0.321¢ |

TABLE No. 5.

OPERATING COST OF POWER PLANT

THREE-QUARTER LOAD

| | Item | Per KW Year $ | Per KW Hour ¢ | Per BHP Year $ | Per BHP Hour ¢ |
|---|---|---|---|---|---|
| a | Fixed Charges | 18.182 | 0.20755 | 12.500 | 0.14269 |
| b | Water | 3.078 | 0.03514 | 2.116 | 0.02416 |
| c | Oil & Grease | 2.560 | 0.02922 | 1.760 | 0.02009 |
| d | Repairs | 2.945 | 0.03362 | 2.025 | 0.02312 |
| e | Wages & Salaries | 6.091 | 0.06953 | 4.187 | 0.04780 |
| | Total without Value of B.F. Gas | 32.856 | 0.37506 | 22.588 | 0.25786 |
| | In round figures | $32.86 | 0.375¢ | $22.59 | 0.258¢ |
| f | Fuel equivalent to Coal @ $2.75 | 14.27 | 0.163 | 9.81 | 0.112 |
| | Total | $ 47.13 | 0.538¢ | $32.40 | 0.370¢ |
| f | Fuel equivalent to Coal @ $3.25 | 16.74 | 0.191 | 11.51 | 0.131 |
| | Total | $ 49.60 | 0.566¢ | $34.10 | 0.389¢ |

## TABLE No. 6.

## OPERATING COST OF POWER PLANT

## ONE-HALF LOAD

| | Item | Per KW Year $ | Per KW Hour ¢ | Per BHP Year $ | Per BHP Hour ¢ |
|---|---|---|---|---|---|
| a | Fixed Charges | 27.777 | 0.31709 | 20.000 | 0.22831 |
| b | Water | 3.711 | 0.04236 | 2.672 | 0.03050 |
| c | Oil & Grease | 3.690 | 0.04219 | 2.660 | 0.03036 |
| d | Repairs | 4.250 | 0.04852 | 3.060 | 0.03493 |
| e | Wages & Salaries | 8.777 | 0.10020 | 6.320 | 0.07215 |
| | Total without Value of B.F. Gas | 48.205 | 0.55036 | 34.712 | 0.39625 |
| | In round figures | $48.21 | 0.550¢ | $34.71 | 0.396¢ |
| f | Fuel equivalent to Coal @ $2.75 | 17.03 | 0.194 | 12.26 | 0.140 |
| | Total | $65.24 | 0.744¢ | $46.97 | 0.536¢ |
| f | Fuel equivalent to Coal @ $3.25 | 19.97 | 0.228 | 14.38 | 0.164 |
| | Total | $68.18 | 0.778¢ | $49.09 | 0.560¢ |

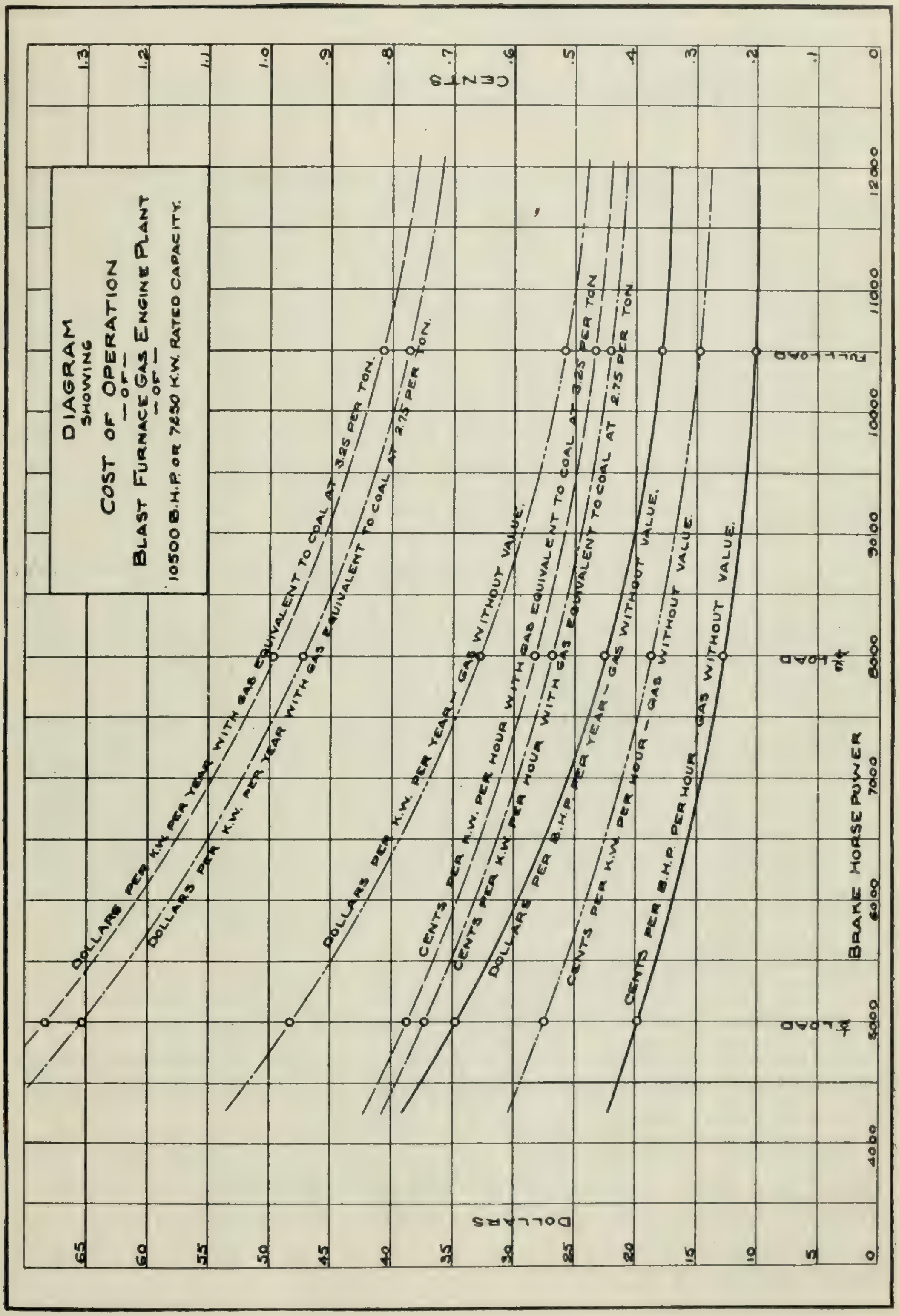


DIAGRAM
SHOWING
COST OF OPERATION
— OF —
BLAST FURNACE GAS ENGINE PLANT
— OF —
10500 B.H.P. OR 7250 K.W. RATED CAPACITY.
DOLLARS PER K.W. PER YEAR WITH GAS EQUIVALENT TO COAL AT 3.25 PER TON.
DOLLARS PER K.W. PER YEAR WITH GAS EQUIVALENT TO COAL AT 2.75 PER TON.
DOLLARS PER K.W. PER YEAR — GAS WITHOUT VALUE.
CENTS PER K.W. PER HOUR WITH GAS EQUIVALENT TO COAL AT 3.25 PER TON
CENTS PER K.W. PER HOUR WITH GAS EQUIVALENT TO COAL AT 2.75 PER TON.
DOLLARS PER B.H.P. PER YEAR — GAS WITHOUT VALUE.
CENTS PER K.W. PER HOUR — GAS WITHOUT VALUE.
CENTS PER B.H.P. PER HOUR — GAS WITHOUT VALUE.
CENTS
DOLLARS
BRAKE HORSE POWER
FULL LOAD
¾ LOAD
½ LOAD

blast furnaces of about 1,200 tons daily capacity, and in addition large steel plants, rolling mill plants, coal and ore mines, coke ovens, boiler shops, machine shops, bridge works, gunnery works, steam turbine works, locomotive works, etc., etc.

The Cockerill Company employ about 15,000 workmen, and their plant is considered to be the largest of its kind in Belgium and west of Germany.

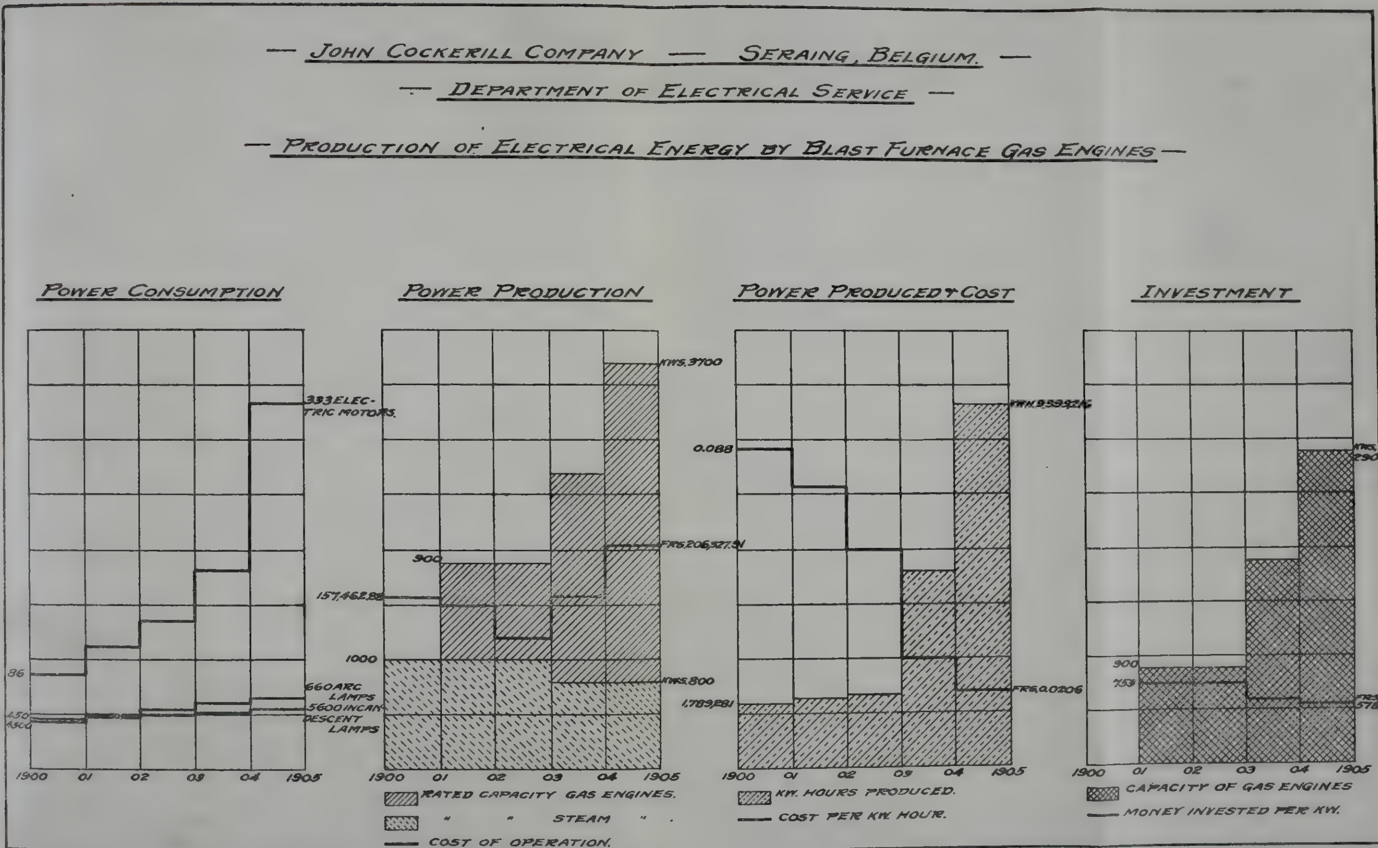
In the first diagram, the power consumption for the past five years is shown. It will be seen to what extent the use of electricity for the various purposes has been developed inside of five years. In 1900 the Cockerill Company had 86 electric motors in use, while in 1905 the number of motors amounted to 333. The lighting outfit consisted in 1900 of 450 arc and 4,500 incandescent lamps, whereas in 1905 the corresponding figures were 660 arc and 5,600 incandescent lamps. In order to produce the power for the electric service, 1,000 K.W. in steam engines were installed in 1900, as shown in the second diagram. In 1901, the first gas engines operating D. C. generators of 900 K.W. total capacity were installed; in 1903, 900 K.W. in gas engines were added and the capacity of the steam engine plant was decreased 200 K.W., so that up to 1905 only 800 K.W. in steam engines were in operation; in 1904, more gas engines were added, bringing the total capacity of the power plant up to 3,700 K.W. This diagram shows that inside of five years the capacity of the power plant has been increased 370%.

The most interesting feature of this diagram is the line showing the cost of operation of the power plant. It will be seen that in 1900 the total operating cost for 1,000 K.W. in steam engines amounted to 157,462.88 Frs.; in 1905, for the total capacity of the power plant of 3,700 K.W., the cost of operation amounted to 206,327.91 Frs. The increase in the operating cost, therefore, amounted to 31% only, whereas the capacity of the power plant had been increased 370%.

Although even in the case that the power plant would have been enlarged by additional steam units, the operating cost would have been reduced in proportion, it is clearly evident that the greatest share of the reduction in the cost of operation is due to the installation of gas engines.

The third diagram shows that the output of K.W. hours produced per year increased from 1,789,281 in 1900 to 9,999,216 in 1905. The cost per K.W. hour fell from 0.088 Frs. in 1900 to 0.0206 Frs. in 1905, so that the cost of one K.W. hour in 1905 was but 25% of the corresponding cost in 1900.

There is no doubt but that the operating cost of the power plant per K.W. hour would have been decreased in the interval of five


— JOHN COCKERILL COMPANY — SERAING, BELGIUM. —
— DEPARTMENT OF ELECTRICAL SERVICE —
— PRODUCTION OF ELECTRICAL ENERGY BY BLAST FURNACE GAS ENGINES —
POWER CONSUMPTION
333 ELECTRIC MOTORS.
86
660 ARC LAMPS
5600 INCANDESCENT LAMPS
1900 01 02 03 04 1905
POWER PRODUCTION
KWS. 3700
FRS. 206,327.91
900
157,462.88
1000
KWS. 800
1900 01 02 03 04 1905
RATED CAPACITY GAS ENGINES.
" " STEAM " .
COST OF OPERATION.
POWER PRODUCED & COST
0.088
1,789,281
FRS. 0.0206
1900 01 02 03 04 1905
KW. HOURS PRODUCED.
COST PER KW. HOUR.
INVESTMENT
900
753
KWS. 2900
1900 01 02 03 04 1905
CAPACITY OF GAS ENGINES
MONEY INVESTED PER KW.

years even in the case of an addition of steam units, as the power factor increased during this time; but referring back to diagram No. 2, it will be seen that the reduction in the cost of power per unit is almost exclusively due to the installation of gas engines. When in 1901, 900 K.W. in gas engines were added to the capacity of the power plant, the total cost of operation dropped, and more so in 1902 when the minimum of operating cost of power plant was reached. In 1903, when 900 K.W. in gas engines were again added, the cost of operation advanced, but the total operating cost in the year 1903-1904 did not exceed the operating cost in 1900-1901, although the capacity of the power plant had been increased 280%. Diagram No. 4 shows the capacity of the gas engines and the amount of money invested per K.W. In 1901 when only 900 K.W. in gas engines existed, 753 Frs. were tied up per K.W. In 1905, when the total capacity amounted to 2,900 K.W. in gas engines, the money invested per K.W. was only 578 Frs. Although the results as indicated in these diagrams could not be used for a direct comparison with blast furnace plants in this country, on account of the considerable difference in the general conditions of operation, cost of labor, etc., so that it would not be appropriate to transpose the operating cost per K.W. hour into American money (0.0206 Frs. would correspond to 0.415c), the striking language of these diagrams, for which I am indebted to Mr. Leon Greiner, chief electrician of the John Cockerill Company, proves conclusively what benefit could be derived from the installation of gas engines for the various power purposes in a modern blast furnace plant.

## DESCRIPTION OF LANTERN SLIDES.

FIGURE 1.

This cut represents an installation of the first 200 H. P. Cockerill gas engine running on blast furnace gas.

This engine was built in 1897 and started in 1898. It operates by means of belt drive an A. C. generator, furnishing electric power for the Cement Mills of the Cockerill Company.

This engine is essentially a duplicate of Mr. Delmare-DeBoutteville's celebrated "Pantin" engine which in the 80's was the largest gas engine in the world. This engine is interesting, inasmuch as it is a so-called side crank engine, a type of bed plate which has later on, been abandoned by all European gas engine builders.

FIGURE 2.

This figure shows a 600 H. P. twin tandem single acting gas engine 27½ in. dia. by 32½ in. stroke, running 150 R. P. M. The engine is direct connected to a 500-volt, 25-cycle, A. C. generator. It is installed in the electrical central station of the Kladno Steel Works and was built by the Breitfeld-Danek Company of Prague, Austrian licensees of the Cockerill Company. This engine is remarkable, because it runs perfectly parallel with two high speed vertical compound steam engines. I wish to emphasize that this engine is of the single acting type giving in four cylinders only one impulse per stroke and is being regulated on the hit and miss principle. The fly-wheel of this engine weighs some 50,000 lbs. and is 18 ft. in diameter, running at 150 ft. circumferential velocity.

FIGURE 3.

Before building double acting gas engines, the Cockerill Company tried to satisfy the demand for gas engines of large capacity by tandemizing their large 51 in. by 55 in. gas cylinders. This cut shows a 1,200 H. P. gas blowing engine which has been duplicated several times.

FIGURE 4.

A view in the central electric station of the John Cockerill Co., at Seraing, Belgium. Since this photograph was taken, two more units of 1,500 H. P. each, representing the latest design of the Cockerill Company with valves on top and bottom, have been added to the capacity of this plant. This is the installation to which the diagram showing the operating cost of the Cockerill central station refers. The two engines in the background are 300 H. P. single acting tandem engines 35½ in. dia. by 39½ in. stroke, running at a speed of 135 R. P. M. The engine in the foreground is a double acting tandem engine of 1,500 H. P. and having 39½ in. dia. cylinder by 43½ in. stroke, running 100 R. P. M.. All engines are direct connected to D. C. generators.

FIGURE 5.

This figure represents a modern double acting tandem gas engine of 1,500 B. H. P. built by the Richardson-Westgarth Company of Middlesboro, the English licensees of the Cockerill Company. This engine represents the latest type of the original Cockerill Gas Engine. Its principal dimensions are cylinder of 39½ in. dia. by 43½ in. stroke, running at 100 R. P. M.

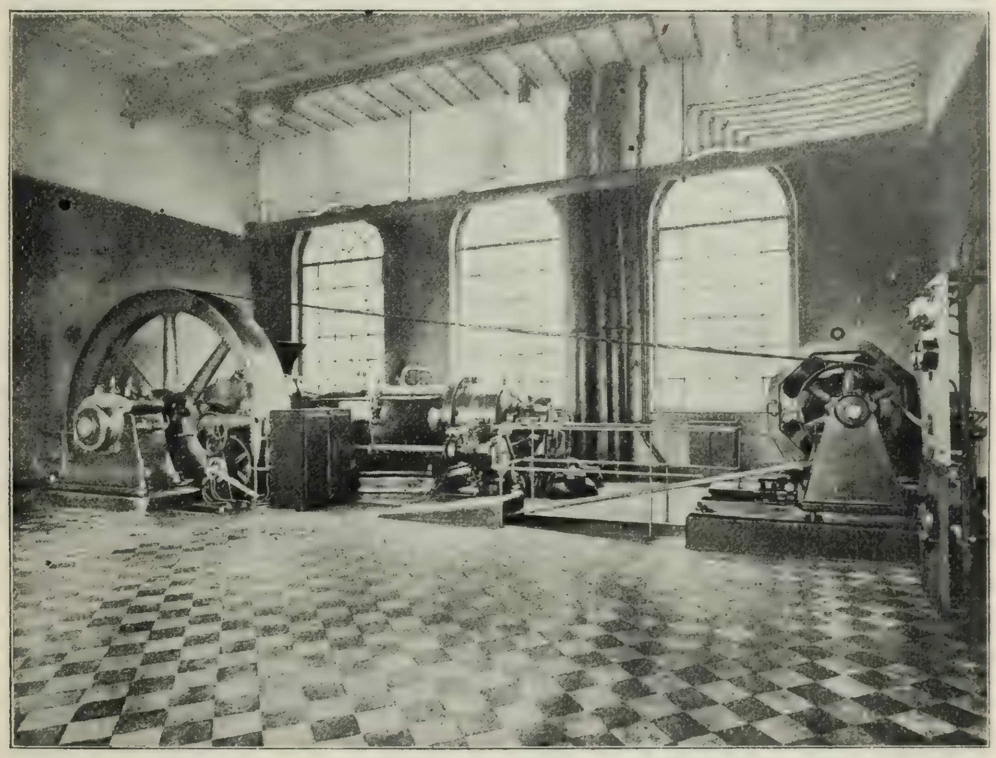


**Fig. 1.**

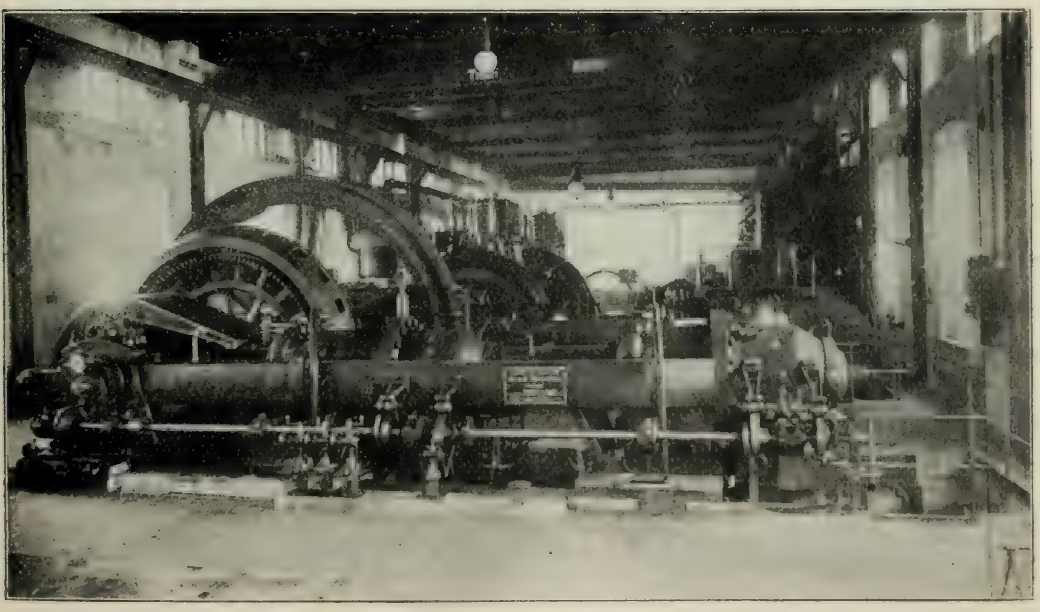


**Fig. 2.**

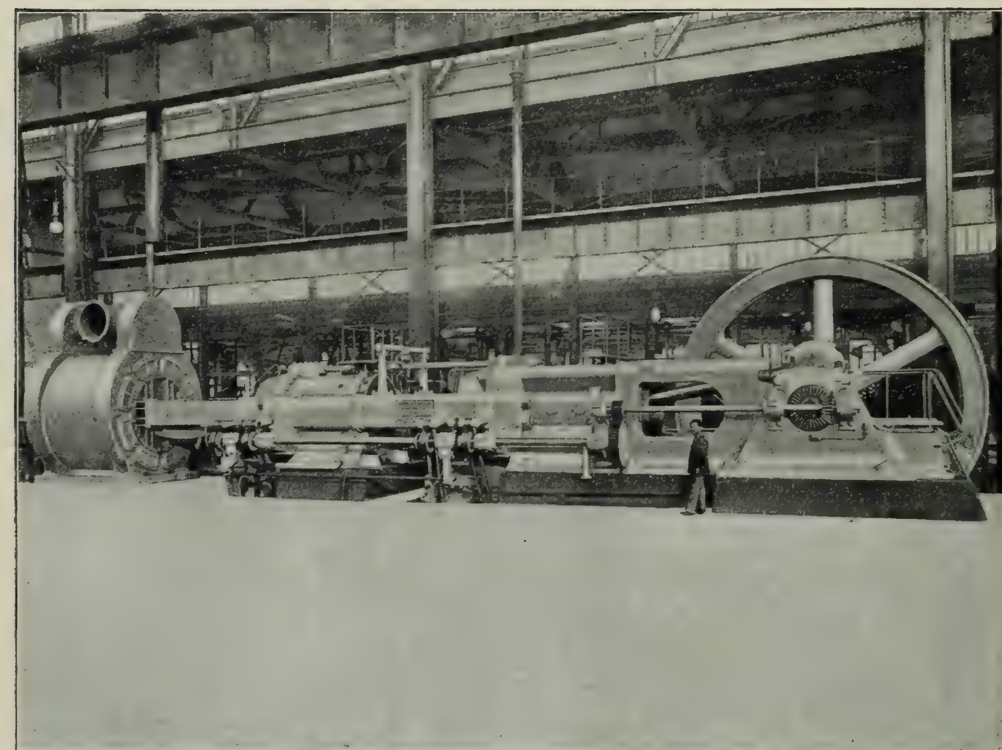


Fig. 3.

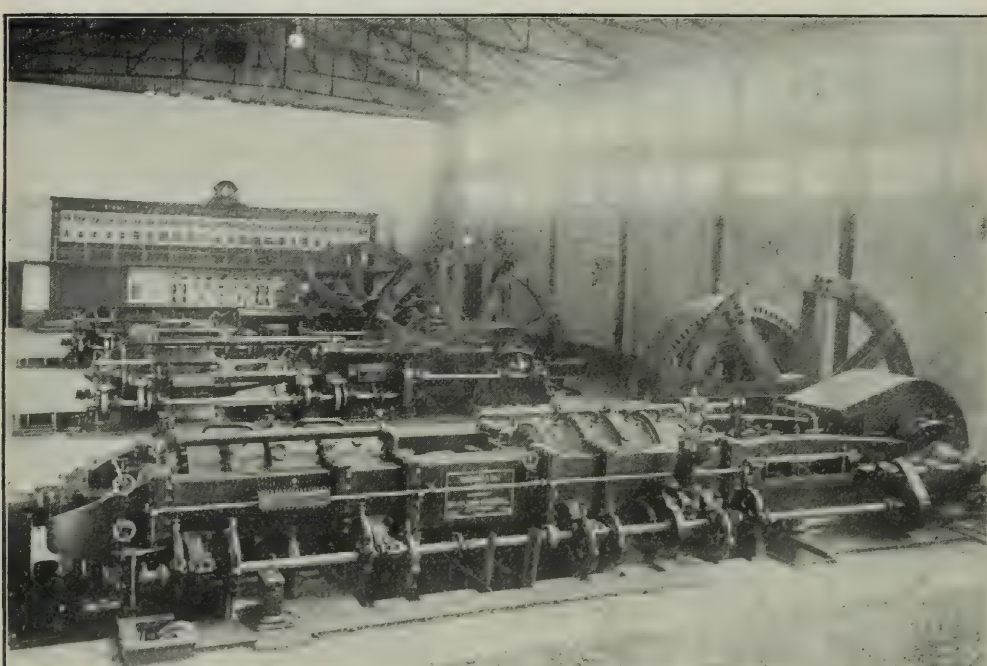


Fig. 4.

FIGURE 6.

Shows the 500 H. P. coke-oven gas engine exhibited at the World's Fair at Liege, Belgium.

FIGURE 7.

This figure represents a modern double acting single cylinder 1,200 H. P. gas blowing engine, 51 in. dia. by 55 in. stroke, the diameter of the blowing cylinder being about 89 in. and is of the Southwark type.

**Fig. 5.**

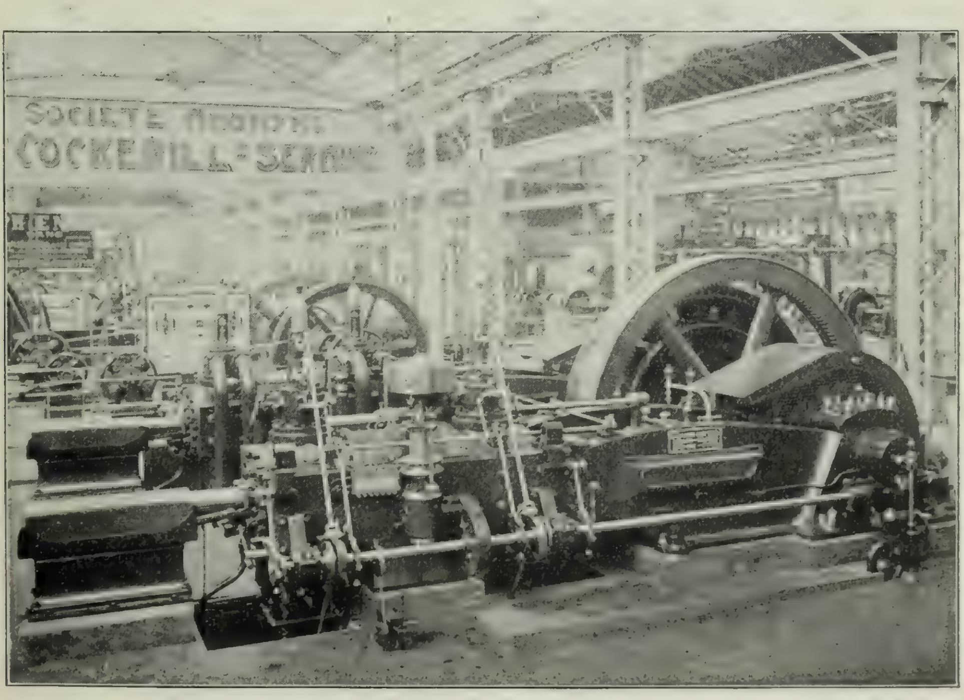


**Fig. 6.**

Fig. 7.

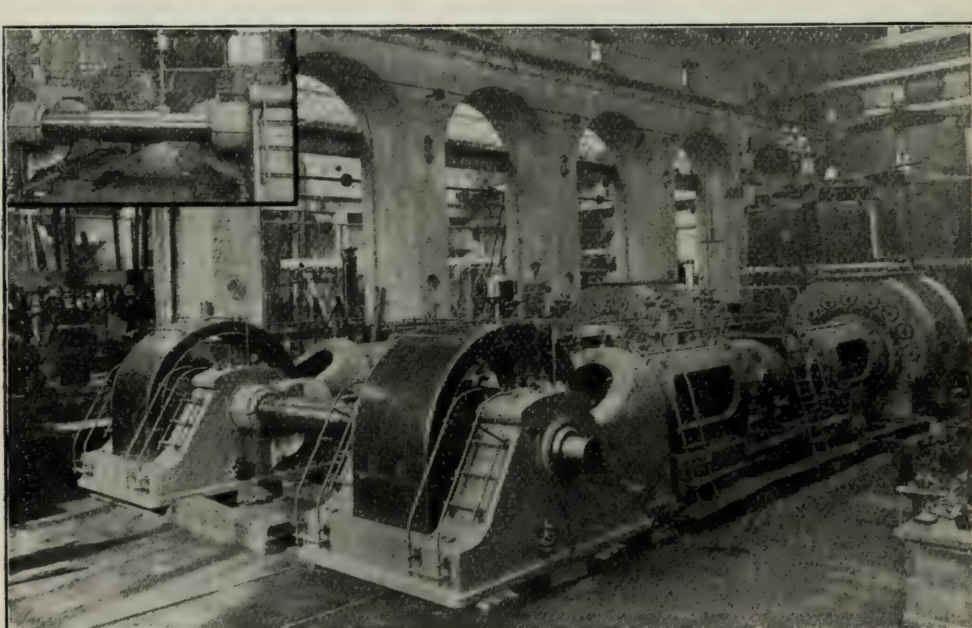


Fig. 8.

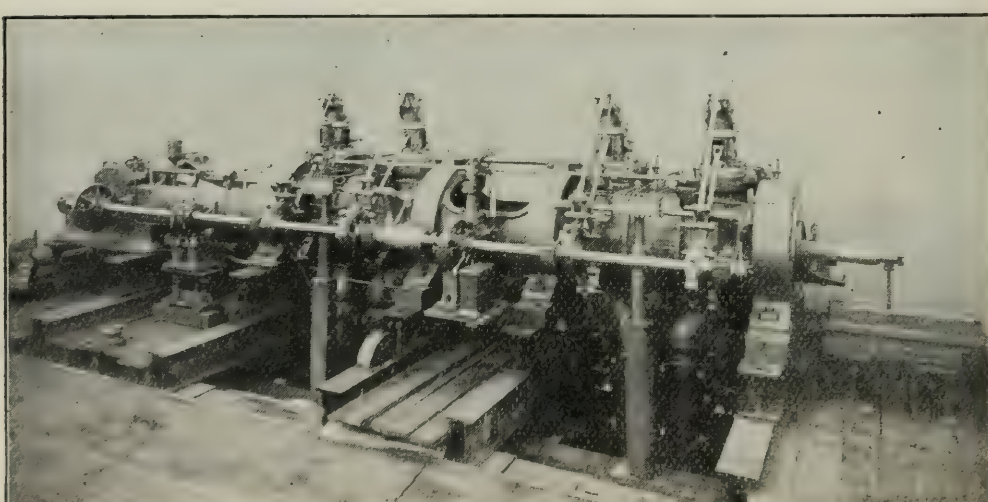


Fig. 9.

FIGURE 8.

This picture represents a view taken in the erecting shop of the Societe Schneider, Le Creusot, France, a concern having a world wide reputation for the excellent quality of their products. The engine shown in this cut is a twin double acting gas blowing engine of about 1,500 B. H. P., which has since been installed at the steel works of Longwy. The upper left hand corner shows an end view of the engine with the main shaft in place—with enlarged section for the fly-wheel.

FIGURE 9.

This is a view of a 500 to 600 H. P. tandem gas engine of the beautiful design chosen by one of the German licensees, Elsassische Machinenbau Gesellschaft of Muelhausen. This engine has about 25 in. dia. of cylinder by 32 in. stroke, running at 135 R. P. M. This engine has a very simple valve gear, the inlet valves and exhaust valves of each cylinder end, being operated by a single eccentric and rolling levers.

FIGURE 10.

Represents a single cylinder double acting blowing engine built by the Breitfeld-Danek Company of Prague, for the steel works at Koenigshof. It has a cylinder of 37½ in. dia. by 47½ in. stroke; running at a speed of 90 R. P. M. The blowing engine arranged in tandem with the gas cylinder is of 65 in. diameter. It has rotary Corliss valves for inlet and the so-called Corliss-type disc valves for the outlet. The capacity is about 14,000 cu. ft. of free air per minute compressed against 10 to 12 lbs. per square inch.

FIGURE 11.

A double acting tandem electric gas engine operating at the Koenigshof steel works. This engine has about 550 H. P. developed in two cylinders, 25½ in. dia. by 29½ in. at 120 R. P. M.

FIGURE 12.

This view shows the installation of three twin double acting blowing engines of 1,800 H. P. each, built by the Elsassische Machinenbau Gesellschaft, for one of the largest steel works in Germany. The gas engine has cylinders of 39½ in. dia. by 55 in. stroke, and blowing cylinders of 69 in. diameter. The capacity is 35,000 cu. ft. of free air per minute against 11 lbs. The pressure can be increased to 22 lbs. by decreasing the volume of air correspondingly. A mean effective pressure of 85 lbs. per square inch has been obtained with this engine. The blowing tubs are fitted with Hoerbiger valves and the efficiency of the engine between the I. H. P. in the gas engine and the I. H. P. in the air cylinder is over 78 per cent. The operation of this engine, the valves of which are operated by eccentrics, is extremely smooth and noiseless. The Cockerill Company and licensees have built up to Jan. 1st, 1906, over 170 engines with an aggregate capacity of over 130,000 H. P.

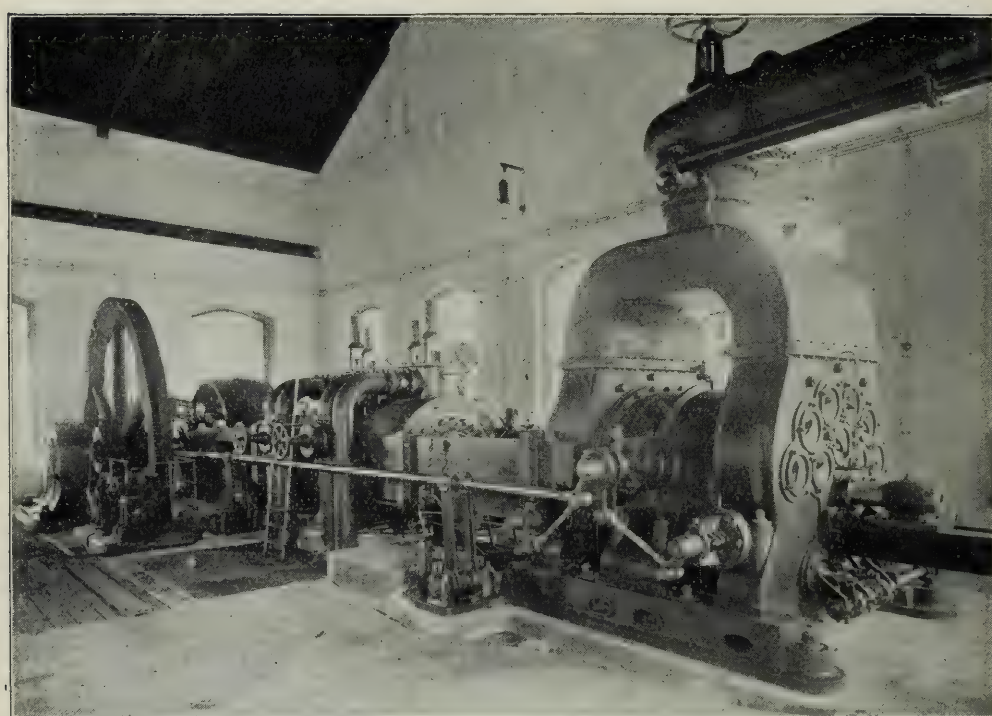


Fig. 10.

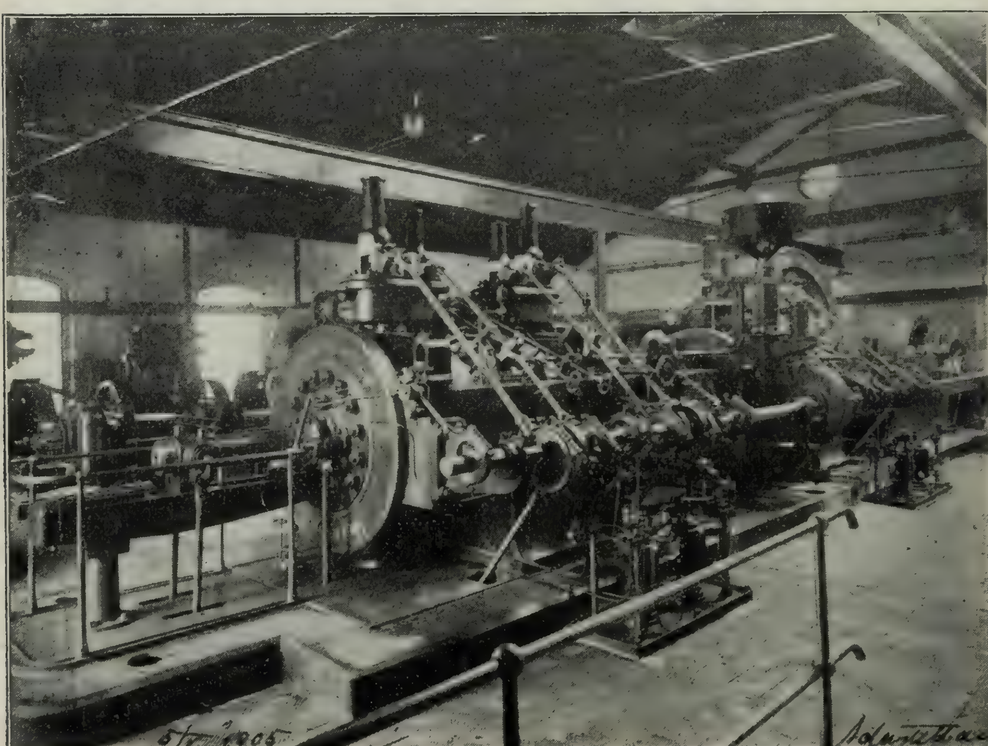


Fig. 11.

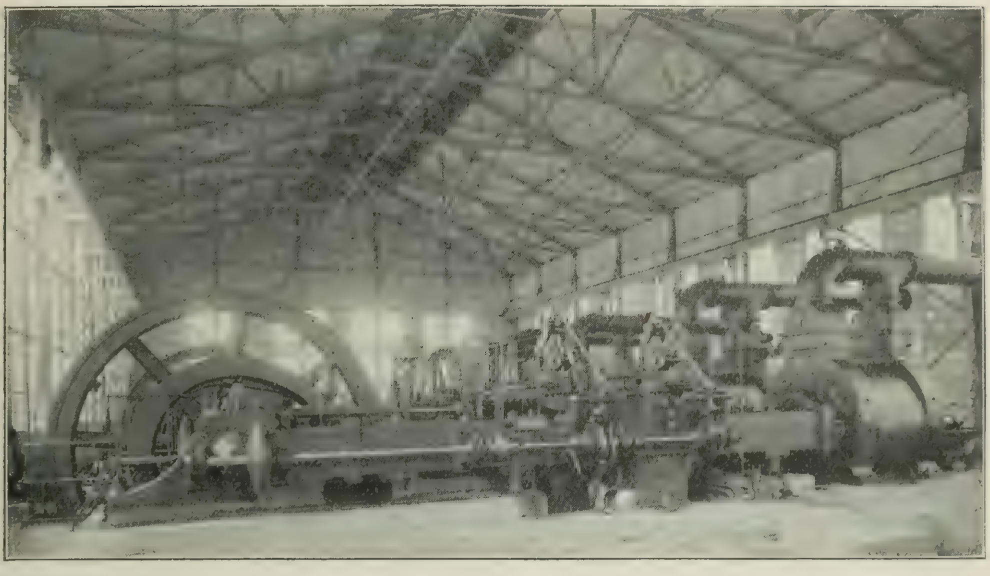


**Fig. 12.**

DISCUSSION.

*Mr. DeWolfe*—(M. W. S. E.)—The question I would ask is a trivial one, i. e., In the gas engine running in parallel with certain steam engines, you speak of the cranks being placed at 180° with twin double acting engines. Why were the cranks placed at 180° rather than 90°?

*Mr. Freyn*—The engine referred to was single acting. With double acting engines the cranks would be placed at 90°.

*Mr. Sargent*—(M. W. S. E.)—I suppose I ought to know in regard to the heat value in blast furnace gas, but are there two thermic values to blast furnace gas, high and low?

*Mr. Freyn*—Yes, there are two values indeed, but it is common practice to give the guarantee of the gas consumption with reference to the "lower" heat value; in other words, to the heat value which remains after deducting the latent heat of the steam carried away by the exhaust gases.

*Mr. Sargent*—Is that from hydrogen in the gas or from water?

*Mr. Freyn*—Mostly from moisture in the gas.

*Mr. Sargent*—If that gas was absolutely dry—if dried by passing it through a sulphuric acid bath—would there be any hydrogen in the blast furnace gas?

*Mr. Freyn*—In Europe practically none, or at least very little; in this country a few per cent.

This hydrogen affects to a certain extent the heat value of the gas but the difference is certainly not very great. The moisture carried along by the blast furnace gas is very annoying from another point of view which is far more important, and that is that the moisture is the carrier of the blast furnace dust. Some good scheme for freezing the gas should be the proper way to remove all the water.

*Mr. Sargent*—Would it pay to freeze it to remove the moisture?

*Mr. Freyn*—To my knowledge, Emil Bian, Superintendent of the blast furnaces at Dommeldingen, was the originator of the idea of freezing the gas with a view to removing the dust by eliminating the moisture, the latter being the medium which carries the finest particles of dust over enormous distances. Mr. Bian has taken out a patent covering this principle of gas cleaning.

*Mr. DeWolfe*—I should like to ask a question in connection with like diagram shown, showing operating cost of gas power plant at the Cockerill Works at Seraing. Does the cost as given in this diagram include the fixed charges and does it alow for the installation of the gas cleaning plant; in other words, does this diagram give the total cost?

*Mr. Freyn*—Yes. That diagram shows the whole operating cost. ing cost.

*Mr. DeWolfe*—It would be interesting to know why the curve giving the total operating cost shows this considerable drop in the year 1902.

*Mr. Freyn*—The years 1901 and 1902 were the years of the greatest improvement in gas engines. In 1902 especially, great improvements were made in the gas cleaning apparatus and consequently a large amount of money which had always been spent for cleaning the gas engines internally was saved. As soon as suitable gas cleaning plants were installed, the gas engines were enabled to run for months without an internal cleaning.

I have a diagram here which shows the operation of the power plant in the works of the John Cockerill Company at Seraing. This diagram shows that the gas engines in the year 1903 were running on an average of nearly 23 hours per day and this includes voluntary stoppages of the engines on Sundays.

I have very often heard the opinion that gas engines are "unreliable" in their operation. If you consider that the engines in the Cockerill power plant were built in 1901 at a time when the general design of the gas engine was very unfavorable for large engines, it must be admitted that the result as shown on this table—the gas engines operating for nearly 23 hours a day during a whole year—is certainly remarkable. Another reason for the drop in the total cost of the Seraing power plant in 1902 was the considerable reduction in the expenditure for lubricants.

The question of oil consumption of a gas engine is very closely connected with the question of gas cleaning. When gas engines are running on clean gas the oil consumption can be reduced considerably.

*Mr. Warder*—(M. W. S. E.)—What does that dust appear to be—mostly from the ore?

*Mr. Freyn*—Mostly from the ore but a little from the coke. In this country where high blast pressures are used, the dust in the blast furnace gas consists of about 75 to 80 per cent of ore and limestone and 25 to 20 per cent from the coke.

*Chairman*—I understand that Mr. Coleman is here and that he can probably tell us something of interest along this line.

*Mr. Coleman*—(of the Lackawanna Iron & Steel Co.)—No, I have nothing to say on the gas engine subject as I have not been in that field very long. We are running two-cycle engines.

*Mr. Freyn*—I know your gas engine plant very well. I understand that your gas engines have been running exceedingly well. I learned from the Chief Engineer of your company, who has charge of the gas engine plant that it is running excellently. I was very much interested to know the cost of operation of this power plant but the Chief Engineer told me that he would not dare to comply with my request but that the cost was away below the best steam engine practice. Later on I understood from other authorities that the cost was about $25.00 per H. P. per year. I would mention that the Lackawanna gas engine plant is not running on full load but somewhere between ¾ and ½ load. At full load the figure which I found in my calculation for the operating cost of a 10,000 H. P. power plant was $17.88. For ¾ load of the power plant, I found the operating cost to be in the neighborhood of $22.59. At ½ load capacity, the cost would be $34.71. The operating cost of the power plant of the Lackawanna Steel Company is $25.00 per H. P. It will be seen that this result of actual experience in a power plant fits in very nicely between the figures which I am giving for ½ and ¾ load of a much smaller power plant. I wish to emphasize the importance of what I believe to be the future of the question of power generation on a large scale, i. e., the future of the gas engine, especially in this country. Although within the past two years great progress has been made in the use of gas engines, they have not found as ardent admirers in the United States as they have in Europe. Just within the last few months a remarkable interest in the question of large blast furnace engines is shown by the numerous inquiries which are being received by the various manufacturers building gas engines in this country. I feel satisfied that in the near future, that large gas engines will be found in the United States just as frequently as in Europe now. The iron masters in this country will have a vital interest in this question and they will have to consider the installation of gas engines very seriously, because the use of gas engines means the reduction of manufacturing cost of pig iron and steel.

*Mr. Mayer*—(M. W. S. E.)—I would like to ask Mr. Freyn how the Theisen washers are constructed.

*Mr. Freyn*—The Theisen gas washer, works on the principle of producing a forced counter stream friction between the gas and the washing liquid. The apparatus consists of a revolving inner drum and of an outer stationary casing. The drum is fitted with oblique blades which are arranged in such a manner that their action counteracts the action of a fan made in one piece with the revolving drum and sucking the gas through the apparatus. The warm dirty

gas enters the apparatus at one end and the cooling and washing water is admitted at the opposite end of the apparatus. The principle of the cleaning process consists in maintaining a film of water traveling in long narrow spirals from the end where the gas leaves the apparatus to the end where it enters. This film of water is produced on the inner surface of the stationary casing, (which is fitted with wire netting in order to increase the washing surface), exclusively by the pressure of the gas exerted by the drum revolving at a high speed. The Theisen centrifugal gas washer fulfills three different operations following each other in different parts of the apparatus. In the first part, the warm gas evaporates, the circulating water film and part of the moistened dust particles are thrown out by the centrifugal force produced by the fan wheel of the apparatus. The water vapors produced in this part of the process mix with the gas, enveloping and moistening the smallest dust particles. In the second part of the washing process, the dust particles burdened by the water vapors are thrown out by the centrifugal force into the circulating water film and thence carried away into the waste water. In the third part, a rapid cooling and condensing action of the warm gas and steam takes place so that the moistened dust and steam, in proceeding on their forced centrifugal spiral way, are gradually absorbed or condensed by the cooler washing water traveling in an opposite direction. By this rapid spiral counter stream circulation of the washing water produced by the pressure of the gas, an incrustation of the washing surface is prevented, as the surface is continually cleansed by the friction of the traveling water film. The gas in the Theisen apparatus is in the closest possible contact with the washing liquid, so that the action of the Theisen washer could most readily be compared with the washing of the hands, inasmuch as heavy rubbing between the washing water and gas takes place in the Theisen washer. The results obtained with this apparatus must naturally be better than could be obtained with any other gas cleaning apparatus. And Mr. Theisen has obtained the most marvelous results in cleaning very dirty blast furnace gas in his apparatus.

There are plants in Germany where the dirty gas contains as much as 10 to 12 grams of dust per cubic meter. This gas, after leaving the Theisen apparatus, does not contain more than 0.02 grams per cubic meter, so that the Theisen gas washer removed over 99.8 per cent of the total quantity of dust carried along by the gas. In other installations where the warm raw gas contained from 3 to 4 grams of dust per cubic meter, the clean gas did not contain more than 0.004 grams per cubic meter, so that the clean gas did not contain more than 0.1 per cent of the dust carried along by the dirty gas. In this particular case, it was found that the gas leaving the apparatus was cleaner than the surrounding atmosphere, which will be most readily understood when considering that the atmosphere around a blast furance plant naturally is very dusty.

*Mr. Warder*—The water carrying this dust is simply wasted, I suppose?

*Mr. Freyn*—No, not necessarily so, because it may be carried into settling tanks and used over and over again.

*Mr. Warder*—Can any use be made of the dust that is collected?

*Mr. Freyn*—As far as I know it is generally dumped and the blast furnace people would be glad if somebody would take it away, as it becomes extremely annoying. I remember of an instance where a blast furance works in Austria had a law-suit on their hands because they dumped the blast furnace dust at a certain place on the outside of their plant near a river. The blast furnace dust contained cyanides which are poisonous and the rain would dissolve these cyanides and wash them into the river. A sugar factory farther down the river which used the water had trouble in making their sugar properly. It was also found that the fish were killed in the river and the fishing club in a nearby city, together with the sugar factory, brought a lawsuit against the blast furnace company. The latter had a very hard time to prove, through experts in this line, that they were compelled to dump the dust. Nevertheless, by order of the courts they had to install quite elaborate settling tanks and water purifiers in order to obviate the condition of affairs as much as possible.

*Mr. Mayer*—Do you know anything about gas washers in Europe where cheese cloth was used?

*Mr. Freyn*—I know of a plant at Kladno in Austria where a little apparatus for measuring the amount of dust in blast furnace gas was invented by Mr. Leo Martius. The principle of this apparatus, which is used almost exclusively nowadays for determining the quantity of dust in blast furnace gas, consists in filtering the gas through Swedish filter paper. As every particle of dust could be retained on the filter in this way, the engineer who superintended the gas engine plant thought that this principle of filtering the gas could be used to great advantage on a large scale. He experimented for some time with cheese cloth or some other tissue and when I asked him later as to how the matter was coming on he told me that it was a failure, because the cheese cloth would clog up in a short time and it was impracticable to clean it continuously. The apparatus which he used for trying this principle was, besides, rather complicated.

*A Visitor*—It would have to be of very large dimensions as well, I suppose.

*Mr. Freyn*—Suppose you had a blast furnace plant of 450 tons capacity, if you only cleaned 30 per cent of the total gas produced, you would have to deal with 2,430,000 cu. ft. of gas per hour or with some 40,000 cu. ft. of gas per minute. It will be seen that it would hardly be possible to treat such a tremendous quantity of gas by filtering it through cloth. This method of cleaning blast furnace gas is after all not so very different from the method which was used almost exclusively some six years ago and consisting in cleaning the

gas by passing it through scrubbers filled with coke and through purifiers containing sawdust, excelsior or other loose material. Installations of this character are extremely expensive and take up so much space that they are cumbersome if larger quantities of gas have to be cleaned.

*A Visitor*—Do you know whether or not sand filters have been used to any extent.

*Mr. Freyn*—I know the man who invented a sand filter for gas cleaning purposes. Constantine Schwarz designed a remarkably ingenious filter in which a sand column moves slowly from the top to the bottom of the sand filter while the gas is passing through the filter at right angles with its surface. A small test filter of this system did not give the anticipated results as the motion of the sand column seems to have been too slow. The consequence was that the filter, which cleaned the gas very nicely for some time, finally clogged up, so that the pressure of the gas was insufficient to force it through the filter.

*Professor McFarland*—(Armour Institute)—What would be the effect of the temperature of the gas upon the cleaning process in the Theisen method.

*Mr. Freyn*—Mr. Theisen himself wants the gas to enter the washer as warm as possible in order to obtain as much an evaporative effect as possible. There is only one objection to doing so, i. e., that in certain cases the blast furnace dust seems to be "hydraulic" so that when the hot gas comes in contact with water, the dust causes incrustation behind the blades of the Theisen washer. It has been found in practice that it is more advantageous to spray the gas with water before it enters the Theisen gas washer, thus reducing its temperature to some extent.

*Mr. Bird*—(Illinois Steel Co.)—What is the usual temperature of the blast furnace gas in Europe?

*Mr. Freyn*—100 to 150° C. or about 200 to 300° F.

*Mr. Bird*—We have nearly twice that in this country. We have 620°. Has the Theisen washer ever been used successfully in this country?

*Mr. Freyn*—There is no Theisen plant in this country for the reason that there are but very few gas engines running on blast furnace gas.

*Mr. Bird*— Do you anticipate any trouble with this much higher temperature?

*Mr. Freyn*—I called Mr. Theisen's special attention to the fact that the American blast furnace gas has far higher temperature than European gas, and he advised me that this would not make any difference whatever. With American blast furnace gas, it would be easier to comply with the Mr. Theisen's theory, i. e., that the gas should enter the Theisen washer at high temperature and at the same time it would be possible by the spraying water, to prevent any incrustations of the apparatus. I mean to say that while the gas has a temperature of 600° F. when leaving the furnace top, it would be

possible to spray it with water and still have a temperature of some 200 or 300° F. when entering the Theisen apparatus. There is no reason to anticipate trouble in the Theisen gas washer in this country, indeed I believe that this apparatus will work still better here than in Europe.

*Mr. Bird*—The fact that the temperature would be injurious to the fan would indicate that you force the gas through. You do not suck it through?

*Mr. Freyn*—Yes, sir, the gas is sucked through the apparatus.

*Mr. Bird*—Then would not the gas be cooled off?

*Mr. Freyn*—No, not perceptibly, although the Theisen apparatus has fan blades at the end where the gas enters and a larger fan made in one piece with the drum on the opposite end. Both fans are sucking the gas through the washer in an opposite direction to the flow of the water.

*Mr. Bergquist*—The suction fan, then, is not sufficient and the gas would have to be forced into the apparatus as well?

*Mr. Warder*—You find it necessary to use two fans instead of one, consequently you do not use any others than the ones in the Theisen apparatus?

*Mr. Freyn*—As explained before, the fans of the drum serve exclusively to pull the gas through the apparatus as the action of the blades is opposed to the stream of gas. In order to obtain this counter steam, a certain amount of power must naturally be exerted but this is necessary for all gas washers without exception. The power consumption of the Theisen gas washer is very small as compared with the power consumption of a hydraulic fan for instance. For 10,000 cu. ft. of gas per hour, the Theisen gas washers consumes 1.2 to 1.5 H. P. In a hydraulic fan water is injected into the gas. The fan which revolves at a high speed throws the water against the casing of the fan and the fan wheel must impart its velocity to the water. The power necessary to do this work is lost completely for this purpose of cleaning the gas. The fan at the same time expels the gas under a comparatively high pressure. This pressure might be as high as 10 inches of water and more. This high pressure of the gas is not at all desirable, because the gas should enter the engines at practically atmospheric pressure. The greater part of the power which must be exerted on the shaft of the fan wheel is therefore wasted. Besides the high power consumption, the fan does not even clean the gas sufficiently for gas engine purpose. In a blast furnace plant where I was occupied with installing a 600 H. P. gas engine, the cleaning apparatus consisted first of a little hydraulic fan. This fan did not prove to be sufficient to clean the gas properly, so that we were finally compelled to install a second fan of larger capacity in tandem. But even then we were unable to reduce the quantity of dust in the clean gas below 0.17 grams per cubic meter, although the power necessary to operate the two fans amounted to 10 per cent of the capacity of the gas engine for which this cleaning plant

had been installed. Blast furnace people are objecting very often against the price and cost of installation of gas cleaning plants in connection with their gas engines, but they forget that in installing gas cleaning plants they are saving money, as the expense for repairs, cleaning the gas engines and for lubricants, as well as the wear of the engines are reduced considerably. The hot blast stoves for blast furnaces or labor saving machines for handling the raw material are very expensive installations also, but in the end the economy balances the cost.

*Mr. Maddock*—Were any of the engines, lantern slides of which you showed us, run with producer gas?

*Mr. Freyn*—No, all of them are operating on blast furnace gas

*Mr. Maddock*—When a plant is running with producer gas, where is the economy—in the gas engine and gas plant, or all in the engine?

*Mr. Freyn*—Both in the gas engine and gas plant, because the gas producer will give as much as 75 to 80 per cent efficiency, while the average efficiency of the boiler plant is but 65 to 70 per cent. As far as the engine itself is concerned, it must be borne in mind that a very economical steam engine operating with superheated steam having a temperature of over 580° F. at the engine stop-valve, consumes 9.49 lbs. of steam per I. H. P. per hour corresponding to 12,318 B. T. U. per I. H. P. per hour. At a mechanical efficiency of 88 per cent, one B. H. P. hour was obtained on 14,000 B. T. U. A modern gas engine will easily produce one B. H. P. hour on 9,000 B. T. U.

*Mr. Maddock*—What is the cost of maintenance of the producer gas plant as compared with the steam plant?

*Mr. Freyn*—I cannot give any definite figures on this, but I understand from the producer people, that the cost of maintenance of a Mond gas producer, for instance, is less than the cost of maintenance of a corresponding boiler plant. A boiler plant, especially an efficient one, requires skilled men to operate it and the necessary appliances, such as feed pumps, superheaters, stokers, etc., and also require considerable attendance. A producer plant requires but little work and most of the men can be unskilled laborers. As far as the operation of the gas engine is concerned, we hear quite often the objection that a gas engine requires operating engineers who must have a special experience in gas engine work. This is most decidedly not the case. In a plant in Germany, where gas engines of an aggregate capacity of 5,000 H. P. were installed several years ago, the men operating the engines were common laborers. My Company has just built a 500 H. P. Sargent Gas Engine for their works at Akron, Ohio, and the erecting engineer who had never seen a gas engine before, has been running this engine now for several months and I would now trust that man with any gas engine.

*A Visitor*—Would you kindly explain the various methods of governing gas engines?

*Mr. Freyn*—Among the various methods, there are three which are used most commonly for governing the gas engine. One of the simplest methods is the throttling of the mixture. By this method the governor acts upon the lift of the mixing valve. The engine sucks in a constant mixture but of variable density during the whole suction stroke. For this reason, the cylinder is filled with mixture under variable pressure and the compression is variable with the load of the engine. This method of governing has the advantage of permitting of a very simple governing mechanism but it has the disadvantage of variable compression which means a high fuel consumption at small loads and entails the impossibility of cushioning the reciprocating parts. The second method consists in cutting off the constant mixture at various points of the suction stroke. This method has the disadvantage of variable compression in common with the first method. The governing scheme which is used mostly in large engines and especially those running on lean gases, as for instance, blast furnace gas, and which has been adopted in this country by the Allis-Chalmers Company in their Nurnberg engine and by the Wellman-Seaver-Morgan Company in their American-Cockerill engine, consists in admitting a variable quantity of a constant mixture which always follows a certain volume of air, so that the cylinder is filled at practically atmospheric pressure at any load of the engine. The compression, therefore, remains constant whatever the load of the engine may be. As the constant mixture always follows the volume of pure air, it is pushed nearer the igniter during the compression stroke so that the ignition of the charge is insured under any circumstances. This method of governing a gas engine has the decided advantage over the afore-mentioned methods of giving a constant compression, thus securing a smooth and quiet operation of the engine at any load, as the inertia of the reciprocating parts, which in a gas engine attains a considerable value, is always balanced by the compression. At the same time this method insures a reduced consumption of gas even at a small load on the engine. This method of regulation is of course only possible when the so-called stratification of the mixture holds true to a certain extent. The fact that gas engines operating on this principle of governing are working entirely satisfactorily, giving good ignition of the charge even at the friction load of the engines, proves conclusively that some kind of stratification must take place. It is easy to understand that a perfect mixing of the pure air charge and of the mixture cannot take place, as there is very little time available for the compression stroke in an engine running at comparatively high speed.

*Mr. Maddock*—Is the water which leaves the Theisen apparatus of any value at all?

*Mr. Freyn*—It would not be of any value on account of the dirt it contains. It would have to be purified if any use should be made of it; however, it can well be used for the Theisen apparatus after the dirt was given a chance to settle out in settling tanks.

*Mr. DeWolfe*—You speak of the Theisen apparatus delivering the gas dryer than it enters. How do they get rid of the humidity introduced in the cleaning process itself?

*Mr. Freyn*—As the gas in the Theisen apparatus comes in perfect contact with the washing water and because of the centrifugal action of the revolving drum and fan, the gas leaving the Theisen washer contains some of the water in the form of water vapor. In order to remove this moisture from the gas, the latter, after leaving the Theisen apparatus, enters the patent Theisen water dust catcher which is situated in front of the Theisen apparatus. In this water dust catcher a separation of the gas from the water takes place, so that cool, dry and clean gas enters the main pipe leading the gas to the engine.

*Mr. Mayer*—What is the compression used in gas engines operating on producer gas?

*Mr. Freyn*—The compression of the mixture depends entirely upon the quality of gas. For blast furnace gas which has a heat value of about 90 B. T. U. per cubic foot, the compression is carried as high as 200 lbs. per sq. in. Producer gas of about 135 to 145 B. T. U. per cu. ft., should not be compressed higher than about 170 lbs. per sq. in. Coke oven gas having a heat value of 550 B. T. U. per cu. ft., should not be compressed higher than about 100 to 120 lbs. per sq. in. For natural gas the compression seldom exceeds 110 lbs. per sq. in. It is a general tendency to compress the mixture as high as permissible, as high compression means low heat consumption. Some people advocate to compress lean blast furnace gas mixtures as high as 240 or even 250 lbs. per sq. in., but I do not think it would be wise or of any particular benefit to exceed 215 lbs., because with very high compression, the expansion is very great and the diagrams are getting slender. The mean effective pressure is therefore reduced unless very high explosion pressures are admitted. The specific power of the engine would therefore be reduced.

*Prof. Chamberlain*—(M.W. S. E.)—Why do you use a cheaper grade of oil in the gas engine cylinder?

*Mr. Freyn*—A great part of the cylinder oil is burned anyway, and besides, it is not necessary to use any high grade oil, as the pistons of our modern gas engines do not bear on the cylinders. They are supported by cross-heads at each end of the cylinder. The oil consumption in gas engines has been reduced remarkably during the past two or three years. As pointed out before, the question of cleaning blast furnace gas has the greatest influence on the oil consumption. Formerly, when we concluded from an experience at the Cockerill Co.'s works at Seraing, that the gas engines would be able to run on raw blast furnace gas in the state in which it is used under the boilers, the oil consumption of the old style single acting gas engines was one of the largest items in the operating expense of such an engine. This was also due to the trunk pistons which bore for their full length on the cylinders,

thus presenting a large surface of friction; but even then the oil consumption of the gas engine compared very favorably with the oil consumption of steam engines using superheated steam of about 500° at the throttle. In one instance the oil consumption for a gas engine plant amounted to 0.15 *heller* per B. H. P. per hour while the expense for lubricants of the superheated steam engine amounted to 0.132 *hellers.*

Since double acting gas engines with enclosed cylinders and with pistons supported on the outside of the cylinders are used and since the gas is subjected to a thorough cleaning process, the oil consumption of the gas engine does not exceed 1½ grams per B. H. P. per hour and the expense for lubricating such an engine is not more than that of a steam engine of the same size using saturated steam.

## "THE LUCIN CUT-OFF" ON THE U. P. R. R.

Abstract of Article in the Century Magazine, (January. 1906), by Oscar King Davis.

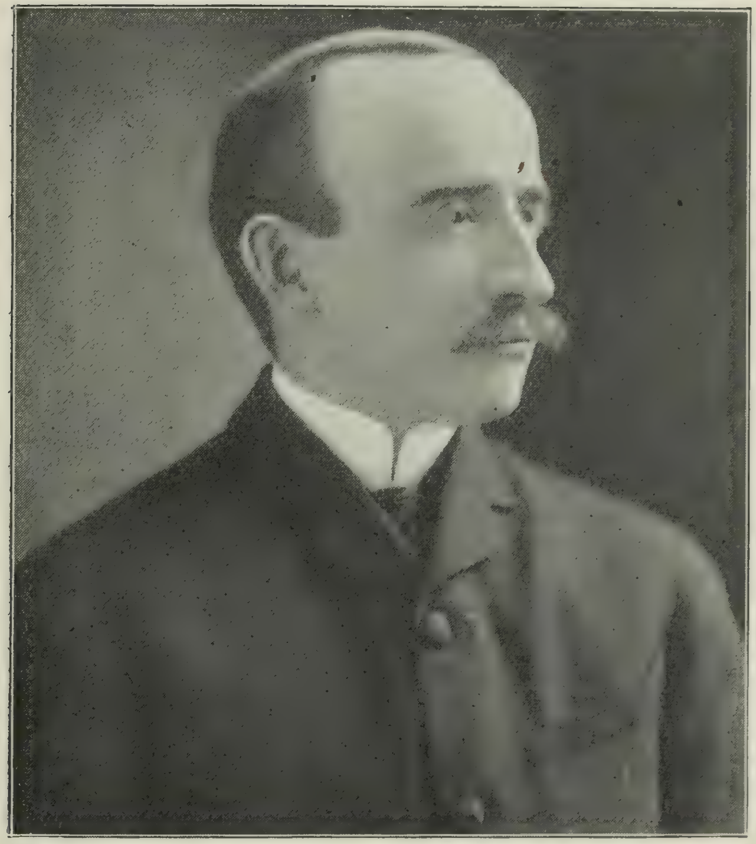
In these days when the literary magazines devote so much space to recounting feats of financial organization, it is refreshing to find an appreciative account of an engineering work published for the general reader. Mr. Davis has told the story of this remarkable piece of engineering in an interesting way, so that every reader of the Century who travels on the Union Pacific will remember when he starts west from Ogden the story of the difficulties met in laying track thirty miles across Great Salt Lake and the courage and perseverance which overcame them.

The Lucin cut-off is one hundred and two miles long; twelve miles of trestle, twenty miles of embankment and seventy miles over the desert. Between Ogden and Lucin, the junction with the main line, it cuts off forty-three miles of distance and the grades and curves necessary to construction in the rough country at the north end of the lake on the old track. One rise of five hundred feet in five and a half miles and another of seven hundred in eleven miles made operating expenses heavy. Three locomotives were required to handle 950 tons. Now one locomotive has pulled 2360 tons over the cut-off (102 miles) in nine hours.

Before undertaking the work, borings were made in the bed of the lake, which showed that the mud of the bottom had been overlaid with crust of salt, soda and gypsum, deposited from the waters. For the trestle, the piles were driven through this crust and the mud beneath to firm bearing, and no trouble was experienced. The fill, however, gave serious difficulty in construction. First the slope of the fill under the very heavy salt water was found to be much less than expected. The under water base of the embankment, was enormously widened, and the shelving away of the material, so little heavier than the water, was only prevented by dumping enormous quantities of rock along with the earth fill. When finally the enbankment had been raised nearly to grade, and engines were first run over the track, sudden sinkings took place. The first engine moved over the track caused a sinking which left the engine standing in two feet of water. The same sections of track sank many times, necessitating successive fillings, until at two sections—Rambo and Bear River, filling to the amount of seven hundred feet had been done. Seventy thousand car loads of rock was dumped from Rambo alone. The effect of this great load of earth and rock filling has been that the soft mud has been pushed from beneath until small islands appeared a hundred yards or so from the track. Twenty miles of forty foot fill is a large order, but to regrade large portions of this fill after sinking totaling seven hundred feet made a stupendous labor. The last sinking in the whole line took place at Rambo in December, 1904. Freight traffic passed over the line in March, 1904, and the line was opened to passenger traffic in September of that year.

ALBERT SMITH, Prof. C. E. Purdue University.

## IN MEMORIAM.



William H. Edgar, November 26, 1905.

William H. Edgar, President of the Dearborn Drug & Chemical Works, and a member of the Western Society of Engineers, died at Hot Springs, Ark., November 26th, 1905, following a short illness.

Mr. Edgar was the son of the late W. H. Edgar, M. D., his mother being Lucy M. Dearborn. He was born in Waddington, New York, November 25th, 1865, and came to Chicago with his parents in 1871.

Following the completion of his scientific studies at the Northwestern University, he at once saw the necessity of investigation of the subject of boiler feed waters, with a view of obtaining sufficient knowledge of the cause of the troubles experienced to ascertain if it were not possible to, in some manner, or by the use of some substances, treat said waters successfully, thereby preventing their deleterious effects. This investigation resulted in his making a specialty of this class of work, and in 1887 the founding of the Dearborn Drug & Chemical Works, which from 1891 until November, 1896,

was maintained as a partnership, at which time Mr. Edgar again became sole owner. Not long following this the Company was duly incorporated under the State Laws of Illinois. Due to Mr. Edgar's geniality, keen perception and exceptional business ability, coupled with the results of extended research in his line, the business had a very marked and rapid growth, and in February, 1898, the capital stock was again increased. Mr. Edgar, however, was always the leading spirit in the enterprise and duirng his life contributed many very valuable papers on the subject of "Boiler Feed Water Treatment" and "Lubrication," and to him is due the present successful treatment of boiler waters with vegetable substances, governed and controlled by results of an analysis of the waters and scientific research and investigation.

Besides his membership in the Western Society of Engineers, (since August, 1902,) Mr. Edgar was a very popular and energetic member of the National Association of Stationary Engineers, also a member of the Northwestern Electrical Association, the American Chemical Society, Chicago Steam Engineers Club, Apollo Commandery, Dearborn Lodge, A. F. & A. M., Oriental Consistory, Medinah Shrine and Chicago Athletic Association.

Mr. Edgar's great desire to see others enjoy themselves, together with his genial manner, endeared him to all. He was well known and deservedly popular, especially amongst the engineers, and one of his greatest prides was the magnificent organization of associates and representatives which he placed around him, and by all these and his many acquaintances he was dearly beloved.

Mr. Edgar is survived by his wife, his mother and two sisters.

(Signed) W. A. Converse,
Wm. Hoskins,
T. W. Snow,
*Committee.*

### Julian S. Hull, December 8, 1905.

Julian S. Hull, a member of this Society, after an illness of several weeks, passed over the great divide on December 8th, 1905. He was born January 31st, 1851, and was graduated from the University of Michigan in 1874. After several years' service on the Denver & Rio Grande and other western roads, in 1883 and 1884 he had charge of tunnel construction on the Mexican Central. He spent several years in the service of MacArthur Bros., contractors, and had charge for them of the construction of a large part of the Missouri, Iowa and Illinois work, on the Chicago Extension of the Sante Fe System. He also later spent a year in South America in the interests of the firm. He served several years in the Engineering Department of the Sanitary District of Chicago, and had charge for it of important construction work through Joliet, Ill. At the time of his death, he had an interest with Mr. John Griffiths in an important contract on the Big Four Road.

Mr. Hull was a man of strict integrity, of large calibre, and great executive ability, but withal so sincere, so modest and so entirely lacking in the arts of the self-promoter, that only his intimate friends and business associates fully appreciated him at his true value.

He was married April 24th, 1884, and leaves his wife, two daughters and a son to mourn his loss.

(Signed) E. H. Lee, *Chairman,*
E. R. Shnable,
L. K. Sherman.

L. S. Olmsted, November 10, 1905.

Lewis Slocum Olmsted was born August 10th, 1826, at Otisco, near Syracuse, in the state of New York. After graduating from the Onondaga Academy, he became a teacher in that institution. He also taught in the schools of several of the nearby villages, continuing his studies while teaching, and subsequently taking the course of engineering in the New York State University.

After leaving the University, he practiced land surveying and engineering, and in 1850 was city surveyor of the city of Syracuse.

He came to Illinois in 1855, and entered the engineer department of the Chicago, St. Paul & Fond du Lac Railroad, which is now a portion of the Chicago & Northwestern Railway. In 1860 he became chief engineer of the Chicago & South Atlantic Railroad, now a part of the Chicago, Indianapolis & Louisville Railway. From 1865 to 1871 he was chief engineer for the Chicago & Alton Railroad, in the construction of the line in Illinois between Jacksonville and Carrollton. From 1871 to 1894 he was chief engineer of the Chicago, Peoria & St. Louis Railway. After this road was placed in the hands of a receiver, in 1894, Mr. Olmsted went to his home in Jacksonville, Ill., where he lived a retired life until his death, on the 10th of November, 1905.

He leaves one daughter, Mrs. Evella Olmsted Grassly, residing with her husband, Frank Grassly, and her daughter, Florence, at 5418 Indiana Avenue, Chicago.

The Western Society of Engineers, of which Mr. Olmsted became a member Feb. 2, 1875, desires, in this brief memorial, to express its appreciation of the personal and professional life of one of its oldest members, and to tender to the surviving members of his family, its sympathy in the loss of one who has been endeared to them for so many years.

(Signed) L. P. Morehouse,
Wm. Sooy Smith,
John E. Blunt,
*Committee.*

Note: The data for the foregoing sketch was furnished by Mr. Olmsted's daughter, Mrs. Grassly.

OFFICE OF

# THE STATE HIGHWAY COMMISSION,

SPRINGFIELD, ILLINOIS.

---

## AN OPEN LETTER.

To the People of the State of Illinois:

FELLOW CITIZENS: The General Assembly of the State of Illinois at its last session, passed a law creating a State Highway Commission. Under that law the Governor of the State has appointed the undersigned members of this commission.

As there seem to be various misconceptions as to the purpose and functions of the Commission we have deemed it advisable to issue the following statement to which we invite your careful attention:

It will be noted that the Commission is not called in the law a hard roads commission or even a good roads commission, but simply a highway commission. This name, we believe, to be significant and to indicate in general its function.

We enter upon this work without preconceived notions or pre-determined policies. It is not made our function by law, nor is it our intention to urge upon the people of this State, or upon those of any section, any special policy as to their respective highways. The determination of the road policy of this commonwealth is vested by law in the public officials of the county, township and road districts, and it is not our duty and is far from our desire to attempt to dictate to any of these officers as to any point respecting their highway policy. In a word, it is not the function or purpose of this Highway Commission or of any of its members to make propaganda for hard roads or State aid in any form. On the other hand, it is made our duty and will be our desire to be of any use or assistance in our power to any or all of the road officials of this State in the performance of their respective duties. It is our purpose to put all the forces of the Commission at the disposal of such officials and to serve them in any way we can.

Over 97 per cent. of the actual highway mileage of the State is earth road, which, for aught we can see, will be for generations to come the prevailing type of roadway. It will be our effort, therefore, to make such a study of the construction, care and improvement of these roads as will yield valuable results for the benefit of every portion of the State, keeping in mind the fact that the improvement of these roads benefits immediately all classes of the community and every part of the State alike.

In some portions of the State the local authorities are constructing gravel and macadam roads. We shall try to offer to these sections of the State such assistance in the way of advice as we may be. able, by drawing up standard specifications, testing the quality of road-building material and finding deposits of material which may be of use in such road construction. In the last mentioned task we have been proimsed the aid of the State Geological Survey. We shall thus hope to make some valuable contributions to this style of road building wherever local authorities desire and local conditions justify it.

We hope further to be of assistance to all departments of the State alike in furnishing on request. advice and specifications as to bridges, culverts, and other forms of structure necessary to highway maintenance. We shall aim to develop an engineering force of such character and training as will

put at the disposal of the poorest road district in the State the best possible expert advice as to all matters falling within its jurisdiction. So that upon questions of grade, drainage, culvert and bridge construction the road-masters of any district or the highway commissioners of any township or the authorities of any county may obtain, upon request, the best advice we can furnish.

The law makes it our duty to collect and publish full statistics relating to the highways of the State, and makes it the duty of local officials to give us the necessary information upon blanks furnished them for this purpose. We make an urgent appeal, therefore, to all road officials to assist us in the performance of this portion of our duty.

The law of the State relating to the employment of convict labor in our State penitentiaries makes it the duty of the boards of management of these institutions to furnish to the Highway Commission such quantities of broken stone as it may call for—this stone to be of a size and quality suitable for use in highway construction. The State Highway Commission is authorized by law to distribute this stone among those road districts of the State asking for it free of all charge to these districts so far as the railways of the State are willing to carry such stone in return for similar stone to be used by them. The quantity of such stone available is, of couse, limited, and it will be distributed in accordance with general regulations intended to insure fairness in distribution among those communities asking for it.

The penitentiaries are also required to manufacture tile suitable for road drainage, and road machinery which will be distributed in the same way. But at present no penitentiary has actually installed a plant for manufacturing such tile. Due notice will be given to the road officers in the State when and where such tile and road machinery can be obtained.

It is further made the duty of the Highway Commission to undertake a careful and thorough examination into the best and cheapest method of highway construction adapted to the needs and conditions of the various portions of the State. Accordingly we shall begin a system of experimentation in the construction, maintenance and improvement of all classes of road which seem adapted to the peculiar conditions of any portion of the State. The cooperation of the highway department of the State University in charge of Professor Ira O. Baker, has been secured for this part of our work and we shall hope to have some valuable results in course of time from this department of our undertaking.

The headquarters of the Commission will be in the State Capitol at Springfield, to which all communications should be addressed.

As state highway engineer, the Commission has engaged the services of Mr. A. N. Johnson, for some time in charge of the highway division in the United States Department of Agriculture at Washington. As one experienced in this sort of work in different parts of the country, his acquaintance with the construction and improvement of earth roads, his careful training as a civil engineer, his knowledge of building all forms of modern highways, will, it is believed, stand the people of this State in good stead. He will be assisted by a competent corps of engineers which will be increased as the public demands may make it necessary.

It is plain that the success of this Highway Commission is absolutely dependent upon the hearty cooperation of county, township and district officials, and we earnestly bespeak such cooperation and support, so that by the combined efforts of state and local officers in this department of public administration the interests of the people of this commonwealth may be most fully served.

Edmund J. James,
Joseph R. Fulkerson,
State Highway Commission.

## ABSTRACT OF THE MINUTES OF THE SOCIETY.

### MINUTES OF ANNUAL MEETING, JANUARY 2, 1906.

The 36th annual meeting (No. 564 of the Society) was held at the Sherman House, Chicago, Tuesday evening, January 2nd, 1906.

The meeting was called to order about 7:15 p. m. with President Carter in the chair, and nearly 100 members and guests present. The reading of minutes of preceding meetings in December was dispensed with as they had been printed in the "Journal."

The Secretary reported from the Board of Direction, the report of the judges of election, of their canvass of the ballots, made that afternoon. This report is appended.

The Secretary would herewith report from the Board of Direction, that at their meeting, held the afternoon of January 2nd, the following were elected into membership in the Society:

| | Grade |
|---|---|
| Mr. Mortimer R. Miller, Waukegan, Ill | Active |
| Mr. John T. Mountain, Chicago | Junior |
| Mr. Jacob Van de Roovaart, Chicago | Active |
| Mr. Walter W. Templin, Chicago | Associate |
| Mr. Julius R. Hall, Chicago | Junior |
| Mr. James R. Jones, Barberton, Ohio | Junior |
| Mr. Otto C. Plessner, Chicago | Associate |
| Mr. Harold P. Weaver, Chicago | Junior |
| Mr. H. W. Swanitz, Du Quoin, Ill., transfer from Junior to | Active |
| Mr. Wm. Artingstall, Chicago, transfer from Junior to | Active |
| Mr. Burchard F. Beckman, Ft. Smith, Ark., transfer from Junior to | Active |
| Mr. Howard M. Ely, Chicago, transfer from Junior to | Active |
| Mr. James E. Montgomery, Chicago | Associate |

Also the following list of new applications were received, and referred to the Membership Committee in the usual manner:

| | Grade |
|---|---|
| John F. Icke, Madison, Wis., transfer from Junior to | Active |
| Dr. Wm. Michaelis, Jr., Chicago | Active |
| Leonard B. Mason, Martin's Ferry, Ohio, transfer from Junior to | Active |
| C. H. McClure, Maywood, Ill | Junior |
| Herbert S. Crocker, Chicago | Active |
| George S. Hill, Chicago | Active |
| Chas. W. Baldridge, Belle Plaine, Iowa | Active |
| Albert U. Stager, Chicago | Associate |
| Arthur Saunders Gore, Salt Lake City, Utah | Active |
| Thos. M. Gardner, Urbana, Ill. | Active |
| Chas. B. Gilson, Chicago | Active |

The annual reports of the treasurer, the secretary and the librarian were not read, but were deferred to be printed in the February, 1906, issue of the Journal.

The business meeting of the Society was a very short one, and the Society and guests then adjourned to the banquet room where the annual diinner was served.

When this had been disposed of, President Carter called the meeeting to order and made his address as retiring president (which is appended), and then introduced president-elect B. J. Arnold, who acknowledged the honor and courtesy of the Society in electing him President for 1906, in a few easy and graceful remarks. President Arnold then turned the meeting over to Mr. Willard A. Smith, M. W. S. E., as Toastmaster for the evening.

With proper introductions and suitable remarks, Mr. Smith called upon, in succession, the following gentlemen, who addressed the meeting on the several subjects as indicated hereafter.

Mr. L. E. Cooley, Past President, W. S. E., The Ownership of Public Utilities.

Mr. Isham Randolph, Past President W. S. E., The Engineer at the Law.

Mr. Onward Bates, Past President W. S. E., The Contracting Engineer and Competitive Bidding.

Prof. D. C. Jackson, elected third vice-president, W. S. E., The Development of University Trained Engineers.

Mr. S. G. McMeen, M. W. S. E. (and vice chairman of the Electrical Section), Electrical Communication.

Mr. B. J. Arnold, President W. S. E., Public Utilities.

The remarks of President Arnold at the end of the evening did not refer to the present question of Municipal Ownership in Chicago, but was an account of what had been and is being done in the electrification of the N. Y. C. R. R. and associate roads, in New York City.

A number of interesting lantern slide views were shown to illustrate Mr. Arnold's remarks.

The meeting then adjourned.

## MINUTES OF EXTRA MEETING, JANUARY 17, 1906.

An extra meeting of the Society (No. 565) was held in the Society rooms Wednesday evening, January 17th, 1906.

The meeting was called to order about 8:30 p. m. with President Arnold in the Chair, and about 35 members and guests present. As there was no business before the Society the President introduced Mr. M. O. Leighton, of the United States Reclamation Service, who addressed the meeting on "High Pressure Sluice Gates," such as are used in connection with high dams in the reclamation work. Lantern slides were used to illustrate his remarks, which showed many points of interest in the design of these large gates, which have to withstand such high hydraulic pressures. Other slides showed the location of some of these dams built in narrow rocky canons, and which are built in an arched form to withstand the pressure of the water in the reservoirs. Discussion (generally as questions relating to the illustrations and the subject) was offered by Messrs. Arnold, Abbott, Finley and others.

At the conclusion, Mr. Finley offered a vote of thanks for the interesting paper presented by Mr. Leighton, which was carried.

The meeting adjourned about 10:15 p. m.

## MINUTES OF EXTRA MEETING, JANUARY 26th, 1906.

An extra meeting of the Society (No. 566) being the 14th regular meeting of the Electrical Section, was held in the Society's rooms Friday evening, January 26th, 1906.

In the absence of the vice-chairman, Mr. S. G. McMeen, and of President Arnold, the meeting was called to order at 8:30 p. m., with Mr. George A. Damon, of the Executive Committee, in the chair, and with about 55 members and guests present. The minutes of the preceding meeting were accepted as printed in the Journal, without reading.

The chairman announced that this was the annual meeting of the Electrical Section, and at his request the secretary explained that, by the rules governing the Electrical Section, their affairs were under the care of an Executive Committee, consisting of a chairman, a vice-chairman, and three other active members of the Section. Also that there was to be elected at this time a chairman and vice-chairman (each for a term of one year) and also one member to serve for a term of three years, to take the place of one member of the Committee, whose term now expired by limitation.

The Executive Committee for the past year consisted of Mr. W. B. Hale, chairman, Mr. S. G. McMeen, vice-chairman, and Messrs. W. G. Carlton,

G. A. Damon, and P. B. Woodworth. Mr. Carlton resigned on leaving the city last year, and was succeeded by Mr. P. Junkersfeld for the remainder of his unexpired term, which terminatetd at this meeting. The election then was for a chairman to take the place of Mr. W. B. Hale, a vice-chairman to succeed Mr. S G. McMeen, and one active member of the section, for a term of three years, to succeed Mr. Junkersfeld. The two other members of the executive committee, Messrs. Damon and Woodworth, are holdovers for terms of one and two years respectively.

On a motion duly seconded and carried, the Chairman appointed a nominating committee, consisting of Messrs. Jas. R. Cravath, K. B. Miller and H. R. King. This committee retired to consider the nominations to be offered the section, and duly reported that they put in nomination the following:

Chairman, Mr. S. G. McMeen, to serve one year.

Vice-Chairman, Mr. P. Junkersfeld, to serve one year.

Member of the Executive Committee, Mr. O. E. Osthoff, to serve three years. The report of the nominating committee was acceptetd without objection or discussion, and on a viva *voce vote* being taken, these were duly elected to their respective offices.

There was no other business to be transactted, and the chairman, Mr. Damon, introduced Mr. Mason B. Starring, General Manager of the Chicago City Railway company, who opened up the general discussion for the evening, "The Best Type of Electric Car for City Service." Mr. Starring, supplemented by Mr. Fleming of the same company, described the "standard car" as adopted by their company, their remarks being illustratetd by a number of lantern slides showing views of the new, large electric cars in service on the Indiana Avenue line in Chicago. The subject was further discussed by Mr. Damon, with illustrations of cars used in the city of Denver, and also some studies of proposed car designs, which possessed some novel and interesting features. The subject was also discussed by Messrs. Munger (of the Metropolitan Elevated Ry. Co.) Schuchardt, Cravath, Warder, Moller, K. B. Miller, and Benj. Glover.

In conclusion Mr. Starring extended a cordial invitation to the members of the Section and of the Society to visit the Shops of the Chicago City Railway Company at Vincennes Ave. and 74th St., and said that a special car would be placed at the disposal of the visitors, at some central point downtown to take them to the shops, at any time which might be mutually agreed upon.

On motion a vote of thanks was extended to Messrs. Starrring and Fleming, who had contributed so much to the instruction and enjoyment of the evening.

The meeting adjourned at 10:20 p. m.

J. H. Warder, Secretary.

## ANNUAL REPORTS.

### REPORT OF THE JUDGES OF THE ELECTION.

January 2, 1906.

*To the Western Society of Engineers, Gentlemen:*

The undersigned judges of election, having canvassed the ballots cast for the officers of this society for 1906, have the honor to report as follows:

| | |
|---|---|
| Total number of ballots received | 350 |
| Total number of ballots rejected as irregular | 17 |
| Total number rejected as not qualified on account of non-payment of dues | 4 |
| Total number ballots counted | 329 |

Number of votes cast for president, 324, as follows:

| | |
|---|---|
| B. J. Arnold | 163 |
| G. A. M. Liljencrantz | 161 |

Number of votes cast for first vice president, 320, as follows:

| | |
|---|---|
| W. L. Abbott | 166 |
| C. F. Loweth | 154 |

Number of votes cast for second vice president, 320, as follows:

| | |
|---|---|
| Andrews Allen | 164 |
| J. W. Alvord | 106 |
| S. G. McMeen | 50 |

Number of votes cast for third vice president, 308, Dugald C. Jackson.
Number of votes cast for treasurer, 308, Albert Reichmann.
Number of votes cast for trustee for three years, 308.

| | |
|---|---|
| F. H. Bainbridge | 178 |
| John Brunner | 89 |
| A. B. Porter | 41 |

Respectfullly submitted,

(Signed) I. F. Stern,
Archibald R. Eldridge,
F. G. Vent.

---

### TREASURER'S REPORT FOR THE YEAR ENDING DECEMBER 31, 1905.

*To the Board of Direction, Western Society of Engineers, Chicago*

I respectfully submit herewith a statement of the treasurer's account for the year ending December 31, 1905, as follows:

#### CASH STATEMENT.

Jan. 1st, 1905, cash in bank subject to check ........ $2,758.01

#### RECEIPTS.

| | | |
|---|---|---|
| Dues | $6,343.45 | |
| Entrance Fees | 647.00 | |
| Subscriptions to Journal | 412.80 | |
| Advertisements (44.37 in trade included) | 2.269.44 | |
| Sales Journal | 160.20 | |
| Interest | 249.91 | |
| Journal Account | 24.78 | |
| Library Account | 87.98 | |
| House Expense | 155.95 | |
| Stationery, postage and exchange | 16.86 | |
| General printing account | 106.25 | |
| Chanute Medal fund account | 50.00 | |
| Investment | 500.00 | |
| | | $11,024.62 |
| | | 13,782.63 |

## EXPENDITURES

| | |
|---|---|
| Journal account | $3,759.90 |
| Library account | 798.94 |
| House expense ($20.00 in trade) | 2,662.18 |
| Stationery, postage and exchange | 681.88 |
| General printing | 672.75 |
| Services | 1,500.00 |
| Furniture and fixtures account ($24.37 in trade) | 245.80 |
| Chanute medal fund account | 18.00 |
| Investment account | 1,500.00 |
| Interest account | 68.83 |
| | $11,908.28 |
| Balance in bank Dec. 31, 1905 | 1,874.35 |
| | 13,782.63 |

## SUMMARY.

| | | | |
|---|---|---|---|
| To credit Western Society of Engineers, Jan. 1, 1905 | $5,191.01 | Investments | 3,500.00 |
| Chanute Medal Fund | 1,067.00 | Cash | 2,758.01 |
| Total | $6,258.01 | | $6,258.01 |

| | |
|---|---|
| 1905, Profit from general accounts | $95.59 |
| Profit from Chanute fund | 32.00 |
| | $127.59 |

Statement Jan. 1, 1906.

| | | | |
|---|---|---|---|
| To credit Western Society of Engineers | $5,275.35 | Investments | $4,500.00 |
| Chanute medal fund | 1,099.00 | Cash | 1,874.35 |
| | $6,374.35 | | $6,374.35 |

| | |
|---|---|
| 1905 dues paid in 1904 | $586.15 |
| 1906 dues paid in 1905 | 87.50 |
| | $498.65 |
| Actual profit for year | $626.24 |

Respectfully yours,

(Signed) ANDREWS ALLEN,
Treasurer.

January 2, 1906.

## SECRETARY'S REPORT.

Chicago, January 2, 1906.

*To the Board of Direction, Western Society of Engineers, Gentlemen:*

Of the affairs of the Society for the year 1905, I beg to report as follows:

The membership of the Society on the 31st of December, 1905, including all those who were elected by your body at your meeting of December 5, 1905, and also including those who have offered their resignations, but which have not yet been accepted, amounts to 856 classified as follows:

| | | |
|---|---|---|
| Honorary members, resident | | 1 |
| Active members, resident | 391 | |
| Active members, non-resident | 277 | |
| | | 668 |
| Associate members, resident | 63 | |
| Associate members, non-resident | 9 | |
| | | 72 |
| Junior members, resident | 76 | |
| Junior members, non-resident | 39 | |
| | | 115 |
| Total | | 856 |

| | | |
|---|---|---|
| To active membership | 42 | |
| To associate membership | 7 | |
| To Junior membership | 30 | |
| | | 79 |
| Resignations accepted | 18 | |
| Deaths | 7 | |
| Dropped from membership | 11 | |
| | | 36 |
| Leaving a net gain of | | 43 |

The names of the seven who died the past year are:
Charles M. Wilkes, active, Jan. 7. 1905.
George Lederle, active March 27, 1905.
William Black, active, May 17, 1905.
J. Holt Gates, active, July 13, 1905.
L. M. Olmsted, active, Nov. 10, 1905.
Wm. H. Edgar, active, Nov. 26, 1905.
Julian S. Hull, active, December 9, 1905.

This net gain in membership of 43 is less than one-third of the gain of 1904, but that year there was the absorption of 53 members of the Chicago Electrical Association, and there was no such body to supply new members to the Society this year.

The number dropped from membership, for failure to pay their dues, is also larger than for either of the preceding years.

During this past year there have been 28 called meetings. This includes the annual meeting of January 3, 1905, and eight meetings of the Electrical section, which were open to all members of the Society. These twenty-eight called meetings include three meetings of a social and popular character, to which ladies were invited, and when refreshments were served, and at which the attendance was large.

Following is a list of the meetings held in 1905.

*Tuesday, January 3:*

The 35th Annual Meeting (No. 536 in the list) was held at the Auditorium and followed by the customary dinner and after-dinner speeches.

*Friday, January 13:*
Extra Meeting (No. 537), being the 6th annual meeting of the Electrical Section, when Mr. C. A. S. Howlett, M. W. S. E., presented "The Commercial Aspects of Engineering."

*Wednesday, January 18:*
Extra Meeting (No. 538). The paper on "The Reinforced Concrete Bridge at Kankakee, Ill.," by Mr. J. B. Marsh, M. W. S. E., was presented.

*Wednesday, February 1:*
Regular Meeting (No. 539). Mr. A. Bement, M. W. S. E., presented his paper on "The Necessity for a Geographical Survey of the State of Illinois."

*Friday, February 10:*
Extra Meeting (No. 540), being the 7th regular meeting of the Electrical Section. Prof. Chas. F. Burgess, of the University of Wisconsin, presented his paper on "The Present Status of Electric Furnace Working."

*Wednesday, February 15:*
Extra Meeting (No. 541). Mr. W. H. Blauvelt, of Syracuse, N. Y., presented his paper on "By-Product of Coke Ovens."

*Wednesday, March 1:*
Regular Meeting (No. 542). The paper by Mr. D. W. Mead, M. W. S. E., on "Recent Improvements in the Plant of the Danville, Ill., Water Company" was read.

*Friday, March 10:*
Extra Meeting (No. 543), being the 8th regular meeting of the Electrical Section. Mr. W. T. Benallack, of the Western Factory Insurance Association, read his paper on "The Electrical Fire Hazard."

*Wednesday, March 15:*
Extra Meeting (No. 544). Prof. L. E. Ashbaugh, M. W. S. E., presented a paper on "The Stadia Intersection Method of Topographical Surveys." Also Mr. T. L. Condron, M. W. S. E., presented his paper on "The Strength of Reinforced Concrete."

*Wednesday, April 5:*
Regular Meeting (No. 545). Prof. L. C. Morin, of Armour Institute, addressed the meeting on "Should Engineers Interest Themselves in Sociology."

*Friday, April 14:*
Extra Meeting (No. 546), being the 9th regular meeting of the Electrical Section. Mr. C. A. Smoot, Jun. M. W. S. E., read his paper on "A Simple Electrical Method of Determining Flux Distribution and Magnetic Reluctance in Odd Shaped Air-Gaps."

*Wednesday, April 19:*
Extra Meeting (No. 547). Mr. Richard T. Fox read his report of eight months' operation in cleaning down town streets of Chicago. A paper by Mr. J. W. Alvord, M. W. S. E., on Street Pavements in Chicago, was also read.

*Wednesday, May 3:*
Regular Meeting (No. 548). The paper by Mr. Willard Beahan, M. W. S. E., on "The Division Engineer in Railway Work," was read.

*Friday, May 2:*
Extra Meeting (No. 549), being the 10th regular meeting of the Electrical Section, was a ladies' night, when Dr. Albert B. Hale gave an illustrated lecture on "The Isthmus of Panama."

*Wednesday, May 24:*
Extra Meeting (No. 550). Messrs. O. Chanute, Willard A. Smith, and T. W. Snow, all members W. S. E., addressed the meeting on "The International Railway Congress of 1903," held in Washington, D. C.

*Wednesday, June 7:*
Regular Meeting (No. 551). Prof. Storm Bull, M. W. S. E., presented his paper on "Steam Turbines."

*Wednesday, September 6:*
Regular Meeting (No. 552). Mr. F. H. Bainbridge, M. W. S. E., presented his paper on "Structural Steel Dams."

*Wednesday, September 20:*
Extra Meeting (No. 553). Mr. John M. Ewen addressed the society on "Foundations in Chicago."

*Wednesday, September 27:*
Extra Meeting (No. 554) (social night). Capt. R. W. Hunt gave an illustrated lecture on British Columbia and Alaska, being an account of the summer meeting of the American Institute of Mining Engineers, at Victoria, B. C., and excursion to the Yukon.

*Wednesday, October 4:*
Regular Meeting (No. 555). "A Metropolitan Park System for Chicago," was presented by Messrs. D. H. Perkins, H. G. Foreman, Judge John Barton Payne, and others.

*Friday, October 13:*
Extra Meeting (No. 556), being the 11th regular meeting of the Electrical Section. Mr. Jas. R. Cravath, M. W. S. E., presented his paper on "Do We Need Better Illuminating Engineering?"

*Wednesday, October 25:*
Extra Meeting (No. 557). Mr. J. J. Harding, M. W. S. E., presented his paper on "Further Tests of Reinforced Concrete Beams."

*Wednesday, November 1:*
Regular Meeting (No. 558). Mr. T. W. Snow read his paper on "Water Softening for Boiler Use."

*Friday, November 10:*
Extra Meeting (No. 559) Ladies' night, being the 12th regular meeting of the Electrical Section. A demonstration of illumination by new arc lamps and of the speaking arc, by Messrs. McMeen, Junkersfield, and Prof. Freeman, was made.

*Wednesday, November 15:*
Extra Meeting (No. 560). Mr. Ellis C. Soper, Jun. M. W. S. E., presented his paper on "A Test of a Portland Cement Plant."

*Wednesday, December 6:*
Regular Meeting No. 561). Mr. Chas. E. Sargent read his paper on "The Prime Mover of the Future."

*Friday, December 15:*
Extra Meeting (No. 562), being the 13th regular meeting of the Electrical Section. Mr. Frank R. McBerty's paper, "Standardization of Methods and Appliances in Telephony," was read.

*Wednesday, December 20:*
Extra Meeting (No. 563). Mr. H. Freyn, of Cleveland, presented his paper on "The Available Power and Cost of Operation of a Power Station for Waste Gases from a Blast Furnace Plant."

(Signed) J. H. WARDER, Secretary.

## LIBRARIAN'S REPORT.

*To the Board of Direction, Western Society of Engineers, Chicago, Gentlemen:*

The librarian begs to sumbit the following report on the library of the Society for the year 1905:

| | |
|---|---|
| Number of books accessioned up to December 31, 1905 | 5597 |
| Number of books accessioned up to December 31, 1904 | 5221 |
| Number of books added to the library during 1905 | 376 |
| These may be classified as follows: | |
| Number of volumes of periodicals (exchanges) bound for the library | 106 |
| Number of books bound, serials exchanged for the Journal, and those given to the library | 217 |
| Number of books bought for the library in 1905 | 53 |
| Money expended on books in 1905 | $183.74 |
| Money expended on binding books in 1905 | 152.00 |
| Money expended on services for library 1905 | 403.91 |
| Money expended on sundries | 59.29 |
| | $798.94 |
| Credit the library, repayment of binding books for members, books sold, old papers sold, etc. | 87.98 |
| Balance charged to library account | $710.96 |
| Money expended on furniture, fixtures, rugs, etc. | $245.80 |
| Total outlay on library, books, furniture, fixtures | $956.76 |

During the past summer there was a thorough overhauling and cleaning of the library and rooms; all books being taken off the shelves, and cleaned, and this accounts for a large part of the outlay for "services."

The space available for bookcases is very restricted, and more room is needed to hold the growing library. Many of our members have been generous in donating books to the library; book publishers are also giving more recognition to the Society, and have been sending books liberally this past year. These are placed in the library, in consideration of a reading notice or review of the books appearing in the Journal. Certain files of desirable periodicals have been added to and completed, which are valuable additions to the library.

The library may now be fairly considered one of the important ones along technical lines, in Chicago, and is freely consulted by the members of the Society, and to a certain extent by the public.

Very respectfully submitted,

(Signed) J. H. Warder, Librarian.

---

## ADDRESS OF RETIRING PRESIDENT MR. E. C. CARTER, AT THE ANNUAL MEETING OF THE WESTERN SOCIETY OF ENGINEERS, JANUARY 2, 1906.

*Gentlemen, Members of the Western Society of Engineers and Visiting Friends:—*

I bid you welcome to this thirty-sixth annual meeting of our Society.

A year ago I had the honor of appearing before you as your choice for president, and for which honor I again sincerely thank you. I now have the pleasure of again greeting you, and of presenting a brief report of the Society, and what has been done this past year.

The Society is in a fairly prosperous condition with a membership of all grades of 856. The net increase the past year is 43. This is less than the gain in 1904, but that was an exceptional year, as the Chicago Electrical

Association was consolidated with this Society, to become the Electrical Section.

The membership of 856 is divided into,

Resident ........................................................................532
Non-resident ...................................................................324

It is very desirable that a considerable increase in the membership be made. The life and prosperity of the Society depends upon its continual growth, and this can best be done by the united efforts of the members. It is not practicable or desirable that the Secretary canvass for new members, but it is the privilege as well as the duty of all members to work for the growth of the society. It is most probable that at least 500 of our active members know one person as an engineer or as one interested in engineering matters, who would be a desirable addition to our membership. Now it is for the present members to have this in mind, and take a little trouble, if need be, to bring in others.

The death roll this past year numbers seven, of which Mr. L. S. Olmsted of Jacksonvillle, Ill., was one of the old timers, he having been a member for over thirty years. The others who have been taken from among us and whose loss we deplore are, Wm. Black, W. H. Edgar, J. Holt Gates, Julian S. Hull, George A. Lederle, and Charles M. Wilkes, all active members of the Society.

The finances of the Society are in a fairly good condition, there being a cash balance in the Bank on the 31st of December, of $1,874.35. The Society has also some interest-bearing investments amounting to $4,500. This includes the gift of Mr. Chanute of $1,000 for the Chanute Medal Fund. The expenses are carefully looked after, but as there is ever a tendency toward an increase for the betterment of the Society's rooms, library, etc., it is a further argument toward a considerable increase in our membership.

The meetings have been kept up regularly, except for the two mid-summer months of July and August. The total number of meetings is 28. which includes eight meetings of the Electrical Section. These 28 meetings include the annual meeting of a year ago, and three social and popular meetings when ladies were invited and refreshments served. Eliminating these four especial meetings, the minutes of the Society show an aggregate attendance of about 1200 at these 24 usual technical meetings, or an average attendance of about 50, and this count includes the visitors and guests. With a resident membership of over 500, the average attendance of our members at these meetings is less than 10 per cent. This is not a good showing, and would indicate a lack of interest in the meetings, and a failure to fully grasp the advantages of membership, "the professional and social intercourse," which is one of the main objects of the Society.

The subjects of papers presented at these technical meetings are varied, and may be classed under the narrower limits of civil, mechanical, and electrical engineering. Reinforced concrete work has received the most attention, as is natural, when so many engineers are at present interested in this form of construction. A meeting of considerable ultimate consequence was held at which the question of "The Necessity for a Geological Survey of the State of Illinois" was considered and as the machinery for such a survey is now in operation we may congratulate ourselves that the Society was instrumental in the results. Two notable meetings were taken up with consideration of gas engines, a matter of importance to power users. The electrical meetings have been well attended, and such subjects as Electric Furnaces, Electric Fire Hazard, Illumination, and Telephony, have been considered.

I wish also to impress upon all members of the Society the necessity of rendering assistance to the Publication Committee in preparing good papers on engineering subjects for presentation to the Society. It is most desirable that members make use of their opportunities to present the results of their engineering study and experience before their fellow membrs, and it is a duty that is due to the Society and the engineering world at large. Further-

more, the benefits to the individual are great, as nothing so clarifies the mind on any subject, as to prepare a written statement of it, and also, the presentation of a paper on some matter of engineering interest, acts as a very valuable introduction of the author to the world of readers of engineering literature. On behalf of the Publication Committee and the Secretary, I would ask you to assist them in their duties by sending in papers, that there may be a supply in advance of the meetings. If the members generally would think of this, there should be no lack, for certainly among our members there are a considerable number who have had such varied and extended engineering experience as would provide the material for many valuable papers.

The library has grown this past year and now numbers nearly 5,600 bound volumes, and a large number of valuable pamphlets. But the space for books and papers is all too restricted; we need more room. The Society and its library is recognized as a public depository for a large number of government publications, such as those from the War and Navy Departments, the Interior Department and particularly of the Geographical Bureaus. The library possesses an almost complete file of the very valuable folios published by the Geographical Bureau and the Topographical Maps of the Geographical Bureau are sent us from time to time, as they are published. The additions to the library this past year include 106 volumes of bound periodicals, and I think it would be well to have more of the technical papers, which we receive in exchange for our Journal, bound up. As a reference library the majority of those who make use of it, desire to refer to such books as they do not possess in their own collections. This is more frequently the bound volumes of technical papers. We have a number of these unbound and bundled up, and thus not available for use in their present condition. I think it would be well to have a number of these bound, and thus made accessible to the reader. But this increase in our supply of valuable books of reference needs room, and the space necessary is hardly available, which again emphasizes a previous remark that more room is needed for the Society and its library. This will entail a greater outlay, which means the need of increased revenue, and this comes back to the necessity of an increased membership. Thus it will be seen that the future welfare and growth of the Society must be a matter of individual effort among he members.

Gentlemen, I thank you for your attention.

I now have the pleasure of introducing our worthy fellow member, Mr. Bion J. Arnold, who succeeds me as President of the Western Society of Engineers for 1906, and hand over to him this emblem of his office.

---

## ADDRESS OF MR. BION J. ARNOLD, PRESIDENT-ELECT AT THE ANNUAL MEETING OF THE SOCIETY, JANUARY 2, 1906.

*Gentlemen and Members of the Western Society of Engineers:*

It is a pleasure for me to be with you this evening, I assure you I tried very hard to be with you at your annual meeting last year. At that time I took a train from Colorado Springs which should have brought me here in time, but owing to the lack of promptness on the part of the Steam Railway operators I arrived here two hours late. I had mislaid my invitation to the dinner; I called up two or three hotels but could find no trace of the Western Society. I concluded that either you were lost or I was lost, and took a 10:30 train for New York without seeing you, as I was compelled to meet an appointment there, although I had hoped to have the pleasure of attending our annual dinner before leaving. This year I took an earlier train, got here this morning, and succeeded in finding you this evening, although a little late. However, I do not want to lay all of the criticism for being late on the steam railroads because tonight I was late although not on account of the poor management of *steam* roads. I intended to come on the Illinois Central but missed a train and took the South Side Elevated. Two

trains went by my station without stopping, and so I was late again. Therefore, I am not quite so enthusiastic on the subject of electric railways as I had expected to be, or as I usually am, but will do the best I can under the conditions, with compliments to Mr. Weston of the Souh Side Road, whom, I believe, is the chief cause of all the present troubles on this road, in his endeavor to improve its capacity, which I am sure he will do when his work of reconstruction is completed.

I do not intend to make a set speech to you now as I am to speak to you a little later. Owing to the uncertainty a candidate feels as to the result of our present method of electing a president, he never knows whether to write a speech of acceptance or of felicitation to his worthy opponent. Under the circumstances I have none written. I wish, however, to express my thanks for and appreciation of, the great honor you have bestowed upon me. While I am somewhat out of touch with the working of the Society, it is through no lack of appreciation of the Society that I have not been with you, for as most of you know my duties require me to be absent from Chicago a great deal. I made these conditions clear to my friends prior to this election, but I have been fortunate in being elected, and will do the best I can to meet your wishes during the ensuing year and join you in working for the welfare of the society. I hope by the end of the year to have been instrumental in securing for you better quarters, additions and improvements to the library and to assist in otherwise bettering the Society's condition. I will do my best I assure you, and again I thank you.

## BOOK REVIEWS.

The Berlin-Zossen Electric Railway Tests of 1903. From the German by Franz Welz, W. E., with introduction relating to Train Resistance by Prof. Louis Bell. The McGraw Publishing Co., New York, 1905. 8¼x11½ inches. Cloth, 100 pages; 38 plates of engravings of machinery, and diagramatic curves of results of tests. Price $3.00.

This book is full of interest to those concerned with electric railway traction. The successful interurban and long distance electric railways are dependent upon their ability to make speed, and if a high speed can be had and maintained with comfort and safety to the traveler by electric traction, the competition of such motive power with steam locomotive service will be yet more severe. Experiments thus far made show that higher speed can be had with electric motors than with steam locomotives. This book is a record of some remarkable work done in such experimentation. The record in all its detail is not only valuable as showing the results obtained, but it also lays down the scheme, to be followed or modified by further experiments. The subject of air resistance, a vital one in all studies of rapid movement, has been carefully considered, observed and recorded. Subsequent study and experimental work may modify the results and conclusions, yet what was accomplished in demonstrating what can be done to obtain such speeds as 100 miles an hour, and at an operating expense is not out of proportion to the advantages.

The diagrams of curves, etc., numbering 40, are worthy of careful study by those concerned in high speed electric traction. These curves show brake tests, air pressure, measurements, train resistance, power consumption, speed current, voltage and power, etc., etc. The concluding paragraph of the book says "These figures prove beyond all doubt that the installation of a high speed railway between Berlin and Hamburg is justified from a commercial standpoint. In the beginning the enterprise will realize a moderate interest on the invested capital, but in the course of time a favorable increase in the profits may be expected." W.

Gas, Gasoline and Oil Engines, including Producer Gas Plants, by Gardner D. Hiscox, M. E., New York. 15th edition, 1906. The Norman W. Henley Publishing Co. Large 8vo cloth; 442 pages, including index; 351 illustrations. Price $2.50 net.

This book has been so popular as to go through several editions since 1897, but the publishers and author considered that the subject had become of such importance, and so many new devices had come out that it was necessary and desirable to re-write the entire book, which was done for this 15th edition

The book consists of twenty-six chapters, of which the last two consist of a list of patents on gas and oil engines since 1875, and the names and addresses of builders of such machinery in the United States and Canada.

The first chapter is introductory, with an historical account of the progress of explosive power.

The second chapter treats on the theory of the gas and gasoline engines with a consideration of heat and its work.

The third chapter treats of the utilization of heat and its efficiency in explosive motors, with tables and diagrams, formulas and examples.

Following chapters relate to retarded combustion, advanced ignition, compression in explosive motors with formulas and tables.

Then comes Chapter VI with causes of loss and inefficiency in explosive motors.

The economy of the gas engine for electric lighting, and the merits of the two and four cycle type is considered in chapter VII, and the succeed-

ing chapter treats of the materials for power in explosive motors, various kinds of gas and gas generating liquids.

Succeeding chapters give details of design, as carbureters, cylinder capacity and proportions, governors and valve gear, ignition by various devices, cylinder lubrication, constructive details of the motor, etc. The measurement of power of such engines, with their management, testing, underwriters' regulations governing their use, etc.

Another chapter takes up the subject of marine motors, with the following chapter discussing motors, bicycles and automobiles.

Chapter XXIV is devoted to gas making apparatus, "gas producers," and the use of gases produced as a by-product in various industrial works as from coke ovens and blast furnaces.

The book fills a place, in giving varied information, to those who desire to become acquainted with gas engine progress, without consulting a host of trade catalogues, relating to this modern subject. It is valuable for reference also, and for the digested information contained therein. S & W.

Practical Pattern Making, by F. W. Barrows. New York, 1906. The Norman W. Henley Publishing Co. Cloth 5¼x7½ inches. 326 pages, including copious index. 141 illustrations. Price $2.00.

This is essentially a practical book for the benefit of the working pattern-maker, and it is a desirable book to put in the hands of the apprentice. If he has the right stuff in him, and desires to make a good mechanic, a careful reading of the book, and frequent references to it subsequently, should be of considerable help in the mastering of his trade. The book could have been improved somewhat, perhaps, if some descriptions of doing the moulding work had been incorporated also.

The first part is introductory, and is followed by chapters on Material and Tools, Examples of Wood Patterns, Metal Patterns, Pattern Shop Mathematics, and finally Cost, Care and Inventory. The book contains a number of illustrations through the text, both of the work and of practical methods of "laying out," but with the great improvement in shop tools for the use of pattern makers, wood lathes, table saws, band saws, surfacers and the like, illustrations of these taken from a modern trade catalogue of pattern makers' tools would have added much to the value of the book, to the studiously inclined workman.

The part relating to Cost, Care and Inventory, is excellent, though modifications of the scheme described will naturally arise in different shops to suit special conditions But any system faithfully carried out is infinitely superior to no system, and this feature of shop management cannot be too ofter insisted upon. The wonder constantly grows that so many shops do manage to get along and make money without any system, relying on the memory of the pattern maker, the foreman or some one else about the shop, and looking over the stock of patterns to see where the article is that is wanted, and not infrequently overlooking it, and finally making up a new and duplicate pattern, a waste of money if only the original one could be found.

Though there is much that could be added to the book to increase its usefulness to the craft, yet taking all in all, it is a valuable addition to our growing list of practical handbooks on technical work. W.

High Tension Power Transmission. A series of papers and discussions presented at meetings of the American Institute of Electrical Engineers, etc. McGraw Publishing Company, New York. 1905. Cloth; 6½x9½ inches; pages 466, including copious index, and many illustrations, diagrams and tables. Price $3.00.

In September, 1902, the Board of Directors of the American Institute of Electrical Engineers appointed a committee known as the Committee on High Tension Transmission, "for the purpose of collecting data respecting present practice in electric transmission at high voltage, and of presenting a report which will indicate the successful methods which are now in operation in such form as to be of immediate value to electrical engineers."

This volume comprises the work accomplished by the Transmission Committee. A large portion of the book consists of discussions by the members on topics selected by the committee, the discussions being led by several short written papers called introductions. In these discussions participated some of the leading experts in design, construction and operation of electric plants, as well as the representatives of the manufacturing companies.

The Transmission Committee also prepared a series of questions on points concerning the features of design and the methods of operation employed in generating stations, transmission lines, and substations of successful existing American transmission plants. The answers to these questions, obtained from authoritative sources, have been classified and tabulated in a manner that renders the information very accessible.

The volme is, therefore, a collection of discussions by experts in the design and manufacture of electrical apparatus for power transmission, and by those skilled in the construction and operation of power transmission plants, and as such should be regarded as an exposition of the state of the art of electric power transmission in America. It is a mine of information, a collection of valuable data for the designing and operating engineeer, and a comprehensive comparison of many successful solutions of similar problems.

The Institute devoted to these papers and discussions the time of two New York meetings in March, 1903, and March, 1904, one day at the Niagara convention in July, 1903, and two days of the special High Tension Transmission convention in Chicago in June, 1904. For this reason the papers are scattered through several volumes of the Transactions of the American Institute of Electrical Engineers. In collecting all of these related papers and discussions in one volume, the publishers have demonstrated the usefulness and broadened the field of the "Institute." By making the information more available for reference they have materially assisted in carrying out the original idea of the Institute of Electrical Engineers of placing the matter in "such form as to be of immediate value to electrical engineeers."

D. W. R.

Gold Dredging, by Capt. C. C. Longridge, M. Inst., M. E., London, "The Mining Journal," 1905. Cloth bound; 6¾x9¾ inches; 194 pages, including index, many illustrations, including some half tones, and 8 folding plates and tables. Price 10 shillings.

While this book is written primarily for English readers and deals more largely with the practice in New Zealand, there are numerous quotations of American source treating of practice of California, British Columbia and Alaska, enough to make the book quite comprehensive.

The book is copiously illustrated, cuts from the various manufacturers have been freely used, but a work of this nature has largely to deal with machinery and this point cannot be seriously criticised, although the frequent introduction of the manufacturer's name somewhat detracts from appearances.

The tabulated information about dredges built for work in New Zealand is unquestionably of value for a man engaged in gold dredging in either California of New Zealand as it gives him comparisons of value. The same is true in regard to description of local methods. A chapter which treats of the selecting, prospecting and valuing of ground is of special interest and value. If prospecting is well done in advance, it eliminates very much of the uncertainty of gold dredging as a business.

The list of fields for gold dredging is of interest, but as the quotations are largely from mining publications of all degrees, they probably lack accuracy, although pointing out possibilities.

The book is indexed. As a whole, while the features of dredging are not presented as saliently as they might be, there is a great deal of information brought together and anyone interested in the subject will welcome the production.

G. S. R.

STANDARD REDUCTION FACTORS FOR GASES, by H. B. MacFarland, Associate Professor of Applied Mechanics, Department of Mechanical Engineering, Armour Institute of Technology, Chicago. Cloth, 8vo, xi. 54 pages. John Wiley & Sons, New York. Price $1.50.

In the testing of Gas Engines, to get results comparable with tests of other engines, it is necessary that the pressure and temperature of the gas be brought to a standard base. The tables in this book are for the purpose of facilitating such computations. There has been a variety of standards employed for temperatures, viz. 32, 59, 60, 62 and 68 degrees by the Fahrenheit scale. The author advocates the use of 62 degrees Fahrenheit as most generally available and useful from a practical point of view, though he has also computed conversion tables referring to a temperature of 32 degrees Fahrenheit and 0° Centigrade. The tension may be based on 30 inches and 760 Mm. of mercury and these tables are based on each of these factors. The introduction of nearly seven pages gives explanation of these tables of of conversion factors and how they may be used. Other tables give the tension of water vapor in inches and in millimeters of mercury, according as the temperature be measured on the Fahrenheit on Centigrade scale. Other tables show the weight in grains of water in one cubic foot of saturated air, according as the temperature be measured on the Fahrenheit or Centigrade scale. Another table that is of value in many computations shows the value of inches of water pressure as measured in inches of mercury and in millimeters of mercury. The final tables gives "factors for the numerical solution of expotential equations," which are frequently encountered in certain lines of work and the solution of which is greatly aided by these tables.

The author has shown commendable industry in making the computations, the results of which are condensed into these tables which should be of considerable interest to those engaged in such lines of investigation.

The paper, presswork and typography are of the excellent quality which characterizes the publications of John Wiley & Sons. W.

TIN DEPOSITS OF THE WORLD, by Sidney Fawns, F. G. S., London, "The Mining Journal," 1905. Full cloth binding; 6x8½ inches; 240 pages, including index, 35 illustrations in the text, 19 full page engravings and 1 folding plate.

The author states his object is "to produce a collected account of tin deposits and methods of tin mining in various parts of the world, and which will be of some practical value to the tin miners and investors." The object is certainly worthy, for as the author states, "The literature of tin mining is at present in a scattered condition."

The forms in which tin is found, and the early history of tin mining, are briefly described in the first chapter and a description of the characteristic formations is given in the second.

The succeeding thirteen chapters take up successively all known deposits, from those in the Malay Peninsula to those in the United States and Alaska, somewhat in the order of relative importance. Necessarily those of the United States are comprised in a couple of pages, for as yet there have been no deposits developed of a sufficient degree of concentration to permit profitable mining, despite the widely advertised Black Hills deposits. Alaska, however, while it has no working mines, the author treats of more extensively, tellling of the promising prospects, and quoting at length from the United States Geological Survey and individuals.

Two widely known mines, the Mt. Bischoff tin mine of Tasmania, and the Dolcoath tin mine of Cornwall are given separate chapters. The latter famous mine is 150 years old, and is still an active producer. Tin ore dressing is briefly described, followed by a chapter on dredging for tin, as practiced in Tasmania and New Zealand. Then comes a description of the methods of tin assaying of various authorities. The closing chapter is de-

voted to the statistics of tin production and is followed by a very complete bibliography.

There is an immense amount of information concentrated in the book, rather too much for easy reading, but for work of reference this undoubtedly has advantages. The chief criticism that can be made is possibly due to the extreme modesty of the author; viz. it is difficult to determine what his own views are on some of the subjects under discussion, for while he acknowledges freely all assistance it is difficult to tell where a quotation ceases and the author's own text begins. The book is indexed and also has a full table of contents which makes if of easy reference.

On the whole, the book has great merit. It is invaluable for anyone interested in tin mining or manufacturing. G. S. R.

DISINFECTION AND DISINFECTANTS. A practical guide for Sanitarians, Health and Quarantine officers, by M. J. Rosenau, M. D., Philadephia, P. Blakiston's Son & Company. 6x8½ inches. Cloth bound; 353 pages, including index and 96 illustrations.

This is a valuable work and may be classed as a standard one on this subject.

The introduction of 17 pages makes clear what is meant by Disinfecting, and wherein it differs from Sterilization, and also the place of deodorants, etc.

Chapter I, considers Physical Agents as sunlight, heat, whether dry or as boiling or as an atmosphere of steam, and also electricity and combustion. Each of these agencies has its own place in the list and each one may be the best, under certain conditions.

Gaseous Disinfectants is treated in Chapter II, and these are considered under their several heads. Formaldehyd, Sulphur Dioxid, Hydrocyanic Acid, Chlorin, Oxygen, Ozone. For many purposes and in many situations, there is nothing so effective as such gaseous disinfectants. Descriptions, with illustrations, make clear the manner of generating and using such and what precautions should be observed in the premises after such disinfecting has been accomplished.

Chapter III, treats of various chemical solutions, as Bichlorid of Mercury, Carbolic Acid, Formalin, Potassium-Permanganate, Ferrous-Sulphate, Zinc-Chlorid, etc., etc. These chemical solutions may be used as sprays on vegetation to remove or prevent the action of some of the lower forms of life, as well as of insects. The apparatus to do such work is shown, and the extent of usefulness, as well as the limitation of such chemical solutions, is clearly set forth.

Methods of destroying a considerable variety of insects, which are objectionable on their own account, as well as being a means of transporting and introducing infection of communicable diseases, is treated in Chapter IV, which includes a list of insecticides, and the manner of their use. The part flies and mosquitos take in the dissemination of communicable diseases has become known and understood within quite recent times, and the suppression or extermination of such agencies is one of the notable features of present sanitary science.

Chapter V treats of the disinfection of houses, ships and objects and has over 50 pages of interesting and valuable instructions.

The final Chapter, VI, considers the communicable diseases, and consists of nearly 100 pages and contains many illustrations of various bacilli, which are the active agent in these diseases, and how they may be guarded against, or removed.

Altogether the book is a valuable one, and should be read by Engineeers whose varied work exposes them to so many forms of infection. A knowledge by them of how and when disinfection should be done, and what disinfectants to use, in one case or another, would often save them, and those under them of much illness, not to say loss of life. W.

Machine Tools, for planing, shaping, slotting, drilling, boring, milling, etc. Their design and construction, by Thomas R. Shaw, Manchester, England The Scientific Publishing Company. Full cloth; 6x8¾ inches; 676 pages, with 8 pages of index, and containing 467 illustrations in the text, and some valuable tables. Price 15 shillings.

This book is a review of practice in the design of machine tools. As the preface states, the work is intended for the use of students and also for those engaged in the design and manufacture of such machinery.

This work is confined to a study and description of a definite class of tools, as indicated in the title, which does not include such where the work is revolved against a cutting tool as lathes, but more especially of that class of tools in which the cuttting tool moves over the work, held stationary, as in shaping, slotting, milling, drilling, etc.

The book is very fully illustrated with half tones and line engravings from machine designs. The various details of the machines are treated of carefully, and the principles of the actions explained, as well as descriptions of the results obtained.

Machines of English, German and American Manufacture are chiefly considered, and the examples shown are of late and "up-to-date" design.

The final chapter, treating of design in general, is well written and contains numerous sketches, with standard dimensions, with data and tables, which are valuable to a designer. The book can be consulted with profit by those about to purchase such tools, as well as those for whom the book was primarily written, as stated in the preface. B. B. C.

---

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the Journal for December, 1905, we have the pleasure to report the following additions to the library and gifts from donors named:

Drexel Institute of Art, Science and Industry, Philadelphia, Year Book of the Department and Courses of Instruction, 1905-6. Pamphlet.

Tratman, E. E. R., M. W. S. E., Chicago,
- Report, Operations of the Engineer Department of the District of Columbia. Pamphlet.
- Incorporation of Capital Railway Co., District of Columbia, 1895. Pamphlet.
- Annual Report, Chief Engineer, Department of Public Improvements, Columbus, Ohio, 1902. Pamphlet.
- Traite Theorique et Pratique de Metallurgie Generale, par L. Babu. Bound volume.
- Proceedings, Annual meeting of Wood Preservers Association, 1905. Pamphlet.
- Association of American Portland Cement Manufacturers, Philadelphia. Concrete Building Blocks, by S. B. Newberry. Bulletin No. 1. Pamphlet.
- National Association of Cement Users, Proceedings of First Convention, Indianapolis, Ind. 1905. Pamphlet.

Lehigh University, South Bethlehem, Pa. "The Cattle Problem of Archimedes," by Prof. Mansfield Merriman. Pamphlet.

Illinois Manual Training School Farm, Glenwood, Ill., Eighteenth Annual Report, 1905. Pamphlet.

Chas. F. Pidgin, Chief Massachusetts Bureau of Statistics of Labor, "Industrial opportunities not yet utilized in Massachusetts." Part 4, 1905. Pamphlet.

Engineering News Publishing Co., New York, N. Y. Index of "Engineering News" for the years 1900-1904 inclusive. Cloth bound.

Scientific Publishing Co., Manchester, England. Cloth bound volume. "Machine Tools, their Design and Construction." 1905. By Shaw.

Tonindustrie-Zeitung, Berlin, Kalendar for 1906. Cloth.

Ohio Geological Survey, Columbus, Ohio, "Revised Nomenclature of the Ohio Geological Formations," by Prosser. Bulletin No. 7. Pamphlet.

Ohio State Highway Department, Columbus, "Convict Labor for Road Improvement," by Huston. Bulletin No. 5. Pamphlet.

Massachusetts Institute of Technology, Boston, "Catalogue of Officers and Students." December, 1905. Pamphlet.

Worcester Polytechnic Institute, Worcester, Mass. "Thirty-sixth Annual Catalogue, 1905-6." Pamphlet.

Norman W. Henley Publishing Co., New York, "Modern Machine Shop Construction, Equipment and Management," by Perrigo. 1906. Cloth.

Norman W. Henley Publishing Co., New York, "Practical Pattern-Making," by F. W. Barrows. 1906. Cloth.

Boston Transit Commission,' Boston, Mass. "Eleventh Annual Report," June, 1905. Cloth.

L. P. Breckenridge, M. W. S. E., Urbana, Ill., "Tests of high-speed tool steels on cast iron." November, 1905. Pamphlet.

Arthur F. Francis, Sec'y, Cripple Creek, Colo. "Official Proceedings of the 16th Trans-Mississippi Commercial Congress at Portland, Oregon, 1905." Pamphlet.

"Official Proceedings of the Thirteenth National Irrigation Congress, at Portland, Oregon, 1905." Pamphlet.

Massachusetts Institute of Technology, Boston, Mass. "Report of the President and Treasurer, January, 1906." Pamphlet.

Carnegie Institution, Washington, D. C. Year Book for 1905. Pamphlet.

M. C. Clark Publishing Co., New York, "Practical Cement Testing," by W. Purves Taylor. 1906. Cloth.

EXCHANGES.

American Society of Mechanical Engineers, New York, "Plans of the Engineering Building in New York." 1905. Pamphlet.

American Water Works Association, "Proceedings, 25th annual convention, 1905." Pamphlet.

Institution of Mechanical Engineers, London, Part 2, 1905. Pamphlet.

American Society for Testing Materials, Philadelphia, "Proceedings, 8th annual meeting, 1905." Pamphlet.

Institution of Civil Engineers, London, "Minutes of Proceedings, Part IV, 1904-5. Pamphlet.

## GOVERNMENT PUBLICATIONS.

Interstate Commerce Commission, Washington, D. C. "17th annual report, Statistics of Railways for the year 1904." Cloth.

U. S. Geological Survey, Dept. of Interior, "The Production of Precious Stones in 1904," by Kunz. Pamphlet.

"The Production of Gold and Silver in 1904," Waldemar and others. Pamphlet.

U. S. Geological Survey. Dept. Interior (Reclamation Work).

"Dam, Main Canal, Earthen Embankments, etc." Payette-Boise Project," Idaho. Specifications No. 68. Pamphlet.

"Contract Drawings accompanying Specification No. 68." Pamphlet.

"Hondo Project, New Mexico, Earthwork of Distributing System." Specification No. 69. Pamphlet.

"Belle Fourche Project, South Dakota, and Uncompahgre Valley Project, Colo. Specifications No. 70 and 71." Pamphlets.

"Sluice Gates and Regulator Gates for Laguna Dam, Yuma Project, California." Specifications No. 72. Pamphlet.

"Payette-Boise Project, Idaho," "Cement." Spec. No. 73. Pamphlet.

U. S. Geological Survey, Dept. of Interior.

"Water Supply and Irrigation Papers Nos. 123, 137-140 inclusive, 142, 147, 151, 152." Pamphlets.

Bulletins Nos. 265, 268, 270, 273." Pamphlets.

"Mineral Resources of the United States, 1904." Cloth.

"Professional Papers Nos. 37 and 40." Pamphlets.

"Results of Primary Triangulation and Traverse. Bul. 276." Pamphlet.

U. S. Coast and Geodetic Survey, Department of Commerce and Labor, "Report of the Superintendent of Coast and Geodetic Survey, July, 1904, to June, 1905." Cloth.

U. S. Department of Agriculture, Bureau of Irrigation. "Plans of Structures in use on Irrigation Canals in the U. S. Bulletin No. 131. Cloth.

U. S. Bureau of the Census, Dept. of Commerce and Labor, "Illiteracy in the United States." Bulletin 26. Pamphlet. "Census of Manufactures, Maryland and District of Columbia, 1905." Bulletin 27. "Census of Manufactures, Kansas. 1905." Bulletin 28. Pamphlet. "Benevolent Institutions, 1904." Cloth. Special Reports.

## TRADE CATALOGUES.

General Electric Co., Chicago, Various bulletins of apparatus. 1905.

Allis-Chalmers Co., Cincinnati, Ohio. Various bulletins from Electrical Departments.

Crane Company, Chicago, 19 pamphlets, various bulletins from March, 1905, to January, 1906.

E. H. Stroud & Co., Chicago, "Crushing, Disintegrating, Pulverizing, Shredding, and other Mining and Milling Machinery." Pamphlet.

Sherwin-Williams Co., Cleveland, O. "Protective Paints for Metal Surfaces," also, "S. W. P. January, 1906." Two pamphlets.

Parker Boiler Co., Philadelphia, "The Parker Boiler." Pamphlet.

National Steam Pump Co., Upper Sandusky, O. Steam Pumping Machinery. Pamphlet.

W. N. Best American Calorific Co., New York City, "Liquid Fuel Equipment for Marine and Stationary Boilers," Pamphlet and three circulars.

American Electric Telephone Co. 15 bulletins in a paper cover, relating to Telephone Apparatus etc. Pamphlets.

## ADDITIONS TO MEMBERSHIP.

Date of Membership

Allison, W. L., with A. T. & S. F. Ry., Railway Exchange, Chicago, Active ..................................Feb. 12, 1906

Artingstall, Wm., 1845 Lexington St., Chicago, transferred from Junior to Active grade ........................ Jan. 9, 1906

Baldridge, Charles W., Belle Plaine, Iowa, Active............Feb. 12, 1906

Barker, Perry, 215 Dearborn St., Chicago, Junior ............Feb. 10 1906

Batte, Thomas R. Jr., Woodward, Oklahoma, Junior........Feb. 21, 1905

Beckman, B. F., with C. B. & Q. R. R., Ft. Smith, Ark., transferred from Junior to Active grade .................Jan. 10, 1906

Crocker, Herbert S., 1247 Monadnock Block, Chicago, Active...Feb. 12, 1906

Ely, Howard M., R. 738 First National Bank Bldg., Chicago, transferred to Active ................................Jan. 9, 1906

Gardner, Thomas M., 1005 W. Oregon St., Urbana, Ill., Active..Feb. 12, 1906

Hall, Julius R., 5828 Ontario St., Austin, Ill. ..................Feb. 7, 1906

Hill, George S., 3038 Groveland Ave., Chicago, Active ........Feb. 14, 1906

Icke, John F., Madison, Wis., transferred to Active grade....Feb. 13, 1906

Jones, James R., Barberton, Ohio, Junior ....................Feb. 13, 1906

Mason, L. B., 319 North 5th St., Martin's Ferry, Ohio transferred to Active grade ............................Feb. 12, 1906

McClure, Clyde H., 614 N. Third Ave., Maywod, Ill., Junior..Feb. 16, 1906

Montgomery, James E., 810 Security Bldg., Chicago Associate Jan. 26, 1906

Mountain, John T., 139 Adams St., Chicago, Junior............Jan.. 9, 1906

Plessner, Otto C., 618 Monadnock Block, Chicago, Associate..Jan. 12, 1906

Swanitz, H . W., Du Quoin, Ill., transferred to Active grade..Jan. 13, 1906

Templin, W. W., 325 E. 57th St., Chicago, Associate ..........Feb. 16, 1906

Van de Roovaart, Jacob, Chief Engr., South Halsted Street Iron Works, Chicago, Active ........................Jan. 10, 1906

Weaver, H. P., 109 Seeley Ave., Chicago, Junior.............Jan. 12, 1906

## CORRECTED ADDRESSES.

Bernhard, B. J., with Western Electric Co., Chicago.
Binkley, Geo. H., 1907 Broadway, Indianapolis, Ind.
Bostwick, L. A., Batavia, N. Y.
Brinckerhoff, H. M., care Wm. Barclay Parsons, 60 Wall St., New York, N. Y.
Brown, Martin L., 6648 Hartwell Ave., Chicago.
Brown, Rodman M., R. 1212 Hartford Bldg., Chicago.
Burke, Ricard O'S., 3146 Rhodes Ave., Chicago.
Caruthers, M. S., Elko, Nevada.
Childs, Oliver W., Street Department, City Hall, St. Louis, Mo.
Dennis, W. F., Vice Pres., Rinehart & Dennis Co., General Railway Contractors, Colorado Bldg., Washington, D. C.
Goodrich, H. C., care Div. Engr. Office, R. G. W. R. R., Salt Lake City, Utah.
Gray, J. C., care Central Georgia Railway Co., Chipley, Ga.
Haines, F. A., care C. & N. W. Ry. Co., Casper, Wyo.
Hegeler, Julius W., Hazel St., Danville, Ill.
Henderson, Lightner, 1553 Monadnock Block, Chicago.
Holmes, Frank, care E. B. Ellis Granite Co., Bethel, Vermont.
Humphrey, F. W. L., 7 Lincoln Place, Chicago.
Huston, R. C., City Engineer, Hattiesburg, Miss.
Kemble, Chas. P., care J. Mohr & Sons, 32 Illinois St., Chicago.

Johnston, J. P., R. 930-34 Marquette Bldg., Chicago.
Martin, Lewis M., Anita, Cass Co., Iowa.
Nash, Frank D., Cornish, I. T.
Nicholl, T. J., 416 Clermont Ave., Brooklyn, N. Y.
Parker, W. A., Res. Engr., Union Pacific R. R. Co., North Platte, Neb.
Pound, N. D., Pres., Pound Engineering and Contracting Co., R. 1215 First National Bank Bldg., Chicago.
Prell, John S., 867 O'Farrell St., San Francisco, Cal.
Prescott, O. R., Asst. M. E., Pfister-Vogel Leather Co., Milwaukee, Wis.
Pruett, Wm., R. 1232 Railway Exchange, Chicago.
Redfield, J. A. S., care C. & N. W. Ry. Co., Rapid City, S. D.
Rainier, F. E., care Riverside Iron Works, Kansas City, Kas.
Redman, C. H., care Div. Engr., C. M. & St. P. Ry. Co., Milwaukee, Wis.
Saner, C. C., 923 Warner Ave., Chicago.
Smith, Albert, Asst. Prof. Purdue University, LaFayette, Ind.
Stevens, Howard E., Pasco, Washington.
Stewart, M. B., 1122 Myrtle Ave., El Paso, Texas.
Trippe, Harry M., care C. & N. W. Ry., Sheboygan, Wis.
Wallace, S. A., care Res. Engr., G. N. Ry., Minot, N. D.
Watkins, Frederick A., care Western Electric Co., New York, N. Y.
Wendland, Wm. R., Bridge Draughtsman, Kenwood Bridge Co., Grand Crossing, Ill.
Wolhaupter, Benj., Sec'y The Rail Joint Co., 29 W. 34th St., New York, N. Y.
Young, J. L., in charge Construction, U. S. Army, Post Honolulu, H. I.

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1906



## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Electrical Section—S. G. McMeen, Chairman, generally the 2d Friday of the month, October to May, inclusive.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL.

# Journal of the Western Society of Engineers.

VOL. XI. APRIL, 1906. NO. 2.


## AREAS OF WATERWAYS FOR RAILROAD CULVERTS AND BRIDGES.


George H. Bremner, M. W. S. E.


DISCUSSION BY JAMES DUN, J. W. ALVORD, AND LOUIS KINGMAN.

*Presented Feb. 7, 1906.*

Until within comparatively recent years, the size of waterways for railroads has usually been decided by the judgment of the engineer in charge, which was governed by the size of the bed of the stream and such information regarding high water as could be easily obtained, and whose one rule was make it large enough.

This method was simple and probably sufficient when timber was cheap and openings large and small were spanned by wooden structures. But as the railroads get older and there is a call for more permanent structures, a more careful study of local conditions and a closer solution of each problem becomes necessary.

Methods, rules and formulas for arriving at the areas of waterways are now as varied as the number of companies using them. The method which I will describe is the gradual growth of a number of years experience and leaves room for much future improvement.

First make a careful study in the field and follow this with a careful choosing in the office of the kind and size of opening. For the field surveys two methods are used:

For *large* bridges the main requirement is a topographical survey of the immediate locality of the bridge. The engineer is furnished with Plans No. 1 and 2, showing the information desired. This calls for a map of the stream for 300 feet each side, a profile of the track for a sufficient distance each side of the crossing to ascertain at what height it is advisable to place the bridge; soundings to ascertain the kind of foundation, for high water marks, contours to aid in locating abutments and piers, and for a few other small items. The drainage area for large bridges is taken from maps and the size of openings chosen with reference to formula shown in diagrams, Figs. 3, 4 and 5.

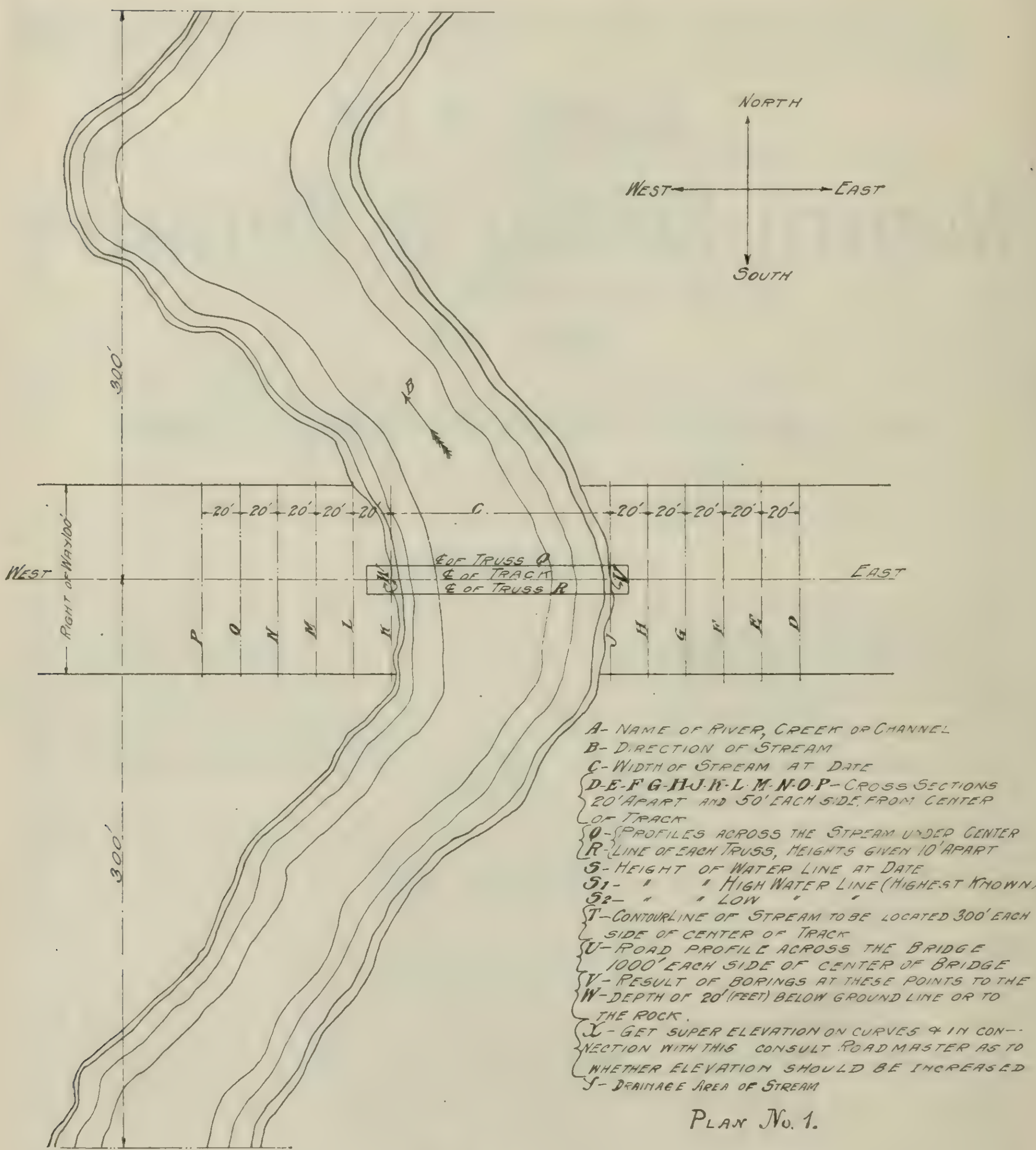
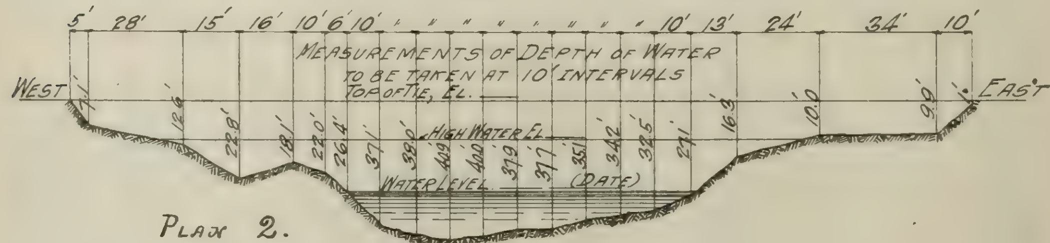


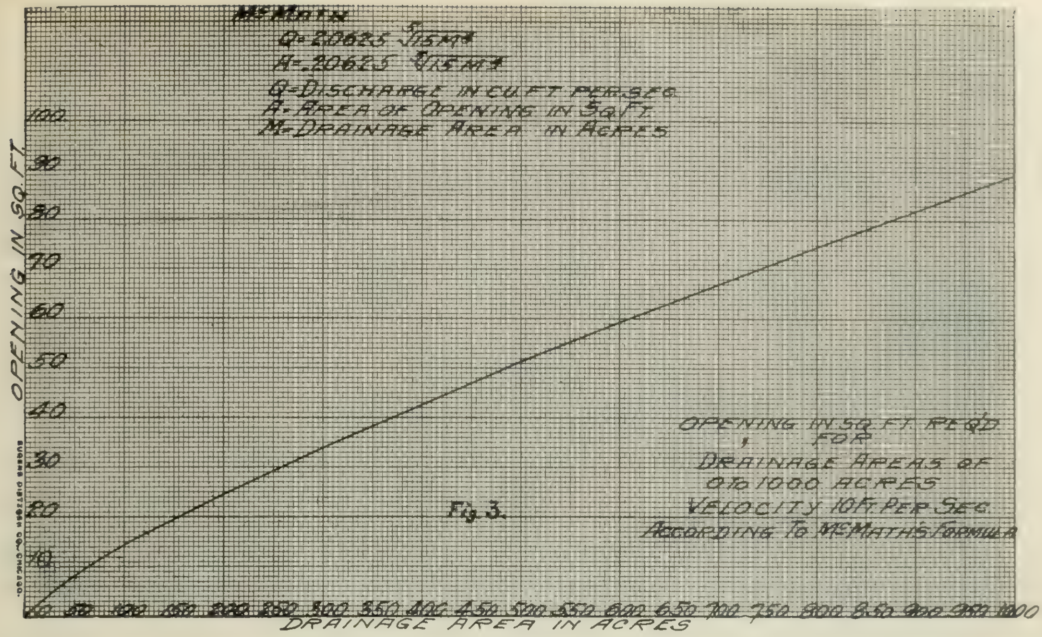

Fig. 1.

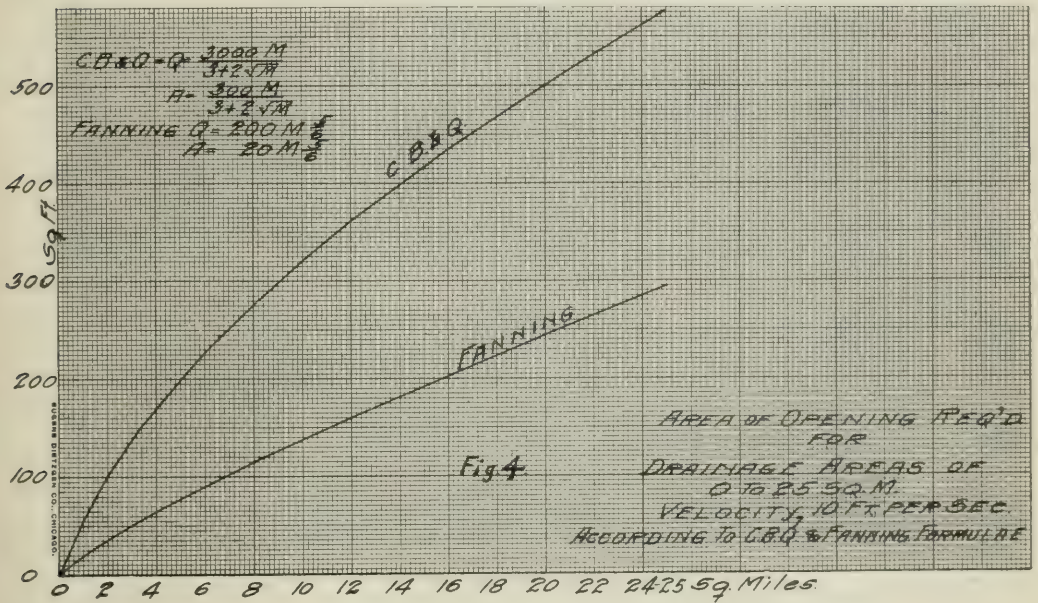


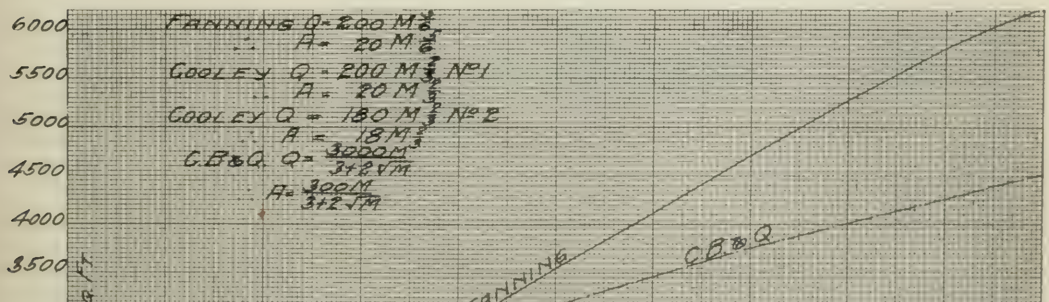

SKETCH SHOWING HOW CROSS SECTIONS OF STREAMS SHOULD BE MEASURED AND PLATTED ON LOCATION PLANS.

NOTE— WHEN THERE IS AN EXISTING BRIDGE, GIVE GENERAL OUTLINES AND DIMENSIONS OF SUB AND SUPERSTRUCTURE, NEVER NEGLECTING DISTANCES FROM TOP OF TIE TO BRIDGE SEATS, FACE OF PARAPET TO CENTER OF PIER, CENTER TO CENTER OF PIERS AND FACE TO FACE OF PARAPETS.

Fig. 2.


McMath
Q=.20625 ⁵√15 M⁴
A=.20625 ⁵√15 M⁴
Q=Discharge in cu. ft. per sec.
A=Area of Opening in Sq. Ft.
M=Drainage Area in Acres
Opening in Sq. Ft.
100
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Drainage Area in Acres
Opening in Sq. Ft. Req'd
for
Drainage Areas of
0 to 1000 Acres
Velocity 10 Ft. per Sec.
According to McMath's Formula
Fig. 3.


C.B.&Q.—Q = 3000 M / (3+2√M)
A = 300 M / (3+2√M)
Fanning Q = 200 M^(5/6)
A = 20 M^(5/6)
Sq. Ft.
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
25 Sq. Miles.
C.B.&Q.
Fanning
Area of Opening Req'd
for
Drainage Areas of
0 to 25 Sq. M.
Velocity, 10 Ft. per Sec.
According to C.B.Q. & Fanning Formulae
Fig. 4.


Fanning Q = 200 M^(5/6)
∴ A = 20 M^(5/6)
Cooley Q = 200 M^(2/3) No. 1
∴ A = 20 M^(2/3)
Cooley Q = 180 M^(2/3) No. 2
∴ A = 18 M^(2/3)
C.B.&Q. Q = 3000 M / (3+2√M)
∴ A = 300 M / (3+2√M)
A—Sq. Ft.
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Fanning
C.B.&Q.
Cooley No. 1
Cooley No. 2
Area of Opening Req'd
for
Drainage Areas of
0 to 1000 Sq. M.
Velocity, 10 Ft. per Sec.
According to Different Formulae
M=Square Miles.
Fig. 5.

For smaller bridges which it may be desirable to fill and put in a culvert, the engineer is furnished with the following blanks, Fig. 6, one of which should be filled out for each bridge:—

H-11-04 1M

Burlington Route

Chicago, Burlington & Quincy Railway Company.

Date, ..................

Information required in regard to BRIDGE No. ............ on ............ Branch,

Between ............ and ............

1. Date of survey ............
2. Name of stream, if known ............
3. Kind of bridge, and length ............
4. Number of tracks and centers of same ............
5. When was bridge last rebuilt? ............
6. Height of bridge, bed of stream to base of rail at each track ............
7. Can, in your opinion, this bridge be channeled out at reasonable cost? ............
8. Number of feet of bridge to be left, if any ............
9. Number of cubic yards of earth required for filling ............
10. Where can this earth be most cheaply obtained, and on Right of Way or not? ............
11. Width of Right of Way at bridge ............
12. Give description of any additional land needed for slopes, if any ............
13. Give drainage area, length and width of same, and state whether slope is steep, medium or flat ............
14. Give effect of high water at this bridge ............
15. Character of drainage area, cultivated, timber or pastural ............
16. Character of soil ............
17. Give high water line below top of tie and area of cross section of channel below this line ............
18. Size and description of pipe or culvert required ............
19. Location of bridge with reference to land lines and names of abutting land owners ............
20. Is bridge used as under crossing or cattle pass? ............
21. Any contract or conditions in deed relating to this ............
22. Does farmer claim contract for undercrossing ............
23. If contract is claimed what can it be bought for? ............
24. Estimated cost of filling ............
25. Estimated cost of rebuilding in kind ............
26. Recommendation of Engineering Department ............
27. Disposition of bridge, and when filled or rebuilt ............
28. Remarks: ............

Note Book No. ............ page ............ Fig. Book No. ............ page ............

Fig. 6.

He is required to answer the various questions on the blank and is given instructions as follows:

### INSTRUCTIONS IN REGARD TO DRAINAGE. AREA SURVEYS FOR FILLING BRIDGES.

This is important work and should be done by the Division Engineer unless otherwise instructed. As far as possible, each question on the accompanying blank should be answered and the best judgment of the engineer used in choosing what kind of opening should be made if the bridge is filled.

Nos. 1, 2, and 3, on the blank do not need any explanation.

No. 4. Do not overlook side tracks.

No. 5. This can be omitted by the Division engineer, as the information will be obtained from the Bridge Department. If shown on the list of bridges meant for survey, insert it in the blank.

No. 6. The bottom of the stream should be taken, but care should be observed that it is not taken in a deep hole, as this height is what you will probably use in estimating the length of culvert.

No. 7. The subject as to channeling out a bridge should be investigated very carefully as it is most desirable to get rid of all openings under the track, that is possible. The points to consider are the nature of soil, the tendency of a channel to wash out the dump and whether it will be necessary to rip-rap or not, the tendency of channel to overflow on to adjoining land, whether there will be any highways or farm crossings to go under, whether it will increase or decrease the drainage area of bridge toward which it is run, whether extra Right of Way will be needed and whether the cost will be excessive. We can afford to pay more for channeling than for a culvert.

No. 8. This is determined a good deal by the drainage and height of bridge, but in bridges with long approaches a number of bents at each end, can frequently be filled and this should be determined by observation in the field. The Bridge Superintendent should be consulted about this.

No. 9. Take accurate cross section of bridge, being careful to get a height at each bent, as this will be necessary in figuring cost of rebuilding in kind. Refer all measurements to top of tie. Roadbed figured 20 ft. wide.

No. 10. If small bridge, consider using slips or wheeled scrapers. If large, see if steam shovel can be used. Character of earth and depth of cut.

No. 11. Measure from fence to fence to be used as a check on description in deeds. The width shown in the deed will be obtained by the District Engineer from the Land Department.

No. 12. This can usually be figured from cross section of bridge.

No. 13. This is by far the most important question to be considered, as the cost, kind, and size of the opening depends greatly on the size of the drainage area and care should be used in getting the same. The tendency is to get the area rather too small rather than too large. It is easier to cut across a field than to go around, but it is better to get it right even if it takes longer and more work. Nothing should be taken for granted and nothing guessed at. Everything should be investigated thoroughly. When you come to a doubtful point, investigate it from all sides. The way you want a field to drain has a great deal of influence on the way it appears to drain. A *doubtful place should be viewed from all four sides,* as it will frequently appear to drain a certain way from one point while from another side you can see that it drains the other way. A ridge a little distance away may look to be the dividing line, but the only way to be sure is to go to the top of it and see the land sloping the other way. Plat up to a 500 ft. to 1 in. scale on thin paper and see that the last course checks fairly close. On plat sketch location of stream 300 ft. up stream and 200 ft. down, showing approximate angle at bridge also the angle and location of nearest land line; also slope of land a hundred feet up and down stream.

Drainage areas of over about three square miles can be obtained from county maps or atlases, but do not take the size of the drainage for granted in any way. You need not go around these extremely large drainage areas if you can find any good plat. All drainage under three square miles, should however, be gone around. To take this drainage area, use a compass reading the needle baring at some point ahead; then step off the distance and so proceed around the drainage area. In this way, one man with a compass can do all necessary work alone. The shape as well as the size of the drainage area is a factor in the size of pipe which should be used. A large, flat area requires a wider and larger pipe than the table might call for, while a long, slim, narrow area would require a smaller one. The steepness of the sides of the area also is important, although there is compensating advantage in the fact that a steep area drains away faster than a flat one, so that except in extreme cases, and where local conditions render back water dangerous, it would not usually be the controlling factor.

No. 14. Is there any back water? If so, what land and how large an area does it cover? Is it the fault of size of opening or would it occur if there were no track there at all? Has bridge ever been washed out?

No. 15. Water drains off faster from timber or pasture land than from plowed land, as the plowed land will retain a great deal more of the water which falls upon it, so that if the area is all cultivated, we can use a smaller pipe.

No. 16. If the soil of the drainage area is sandy, a much smaller pipe can be used than if it is a clayey soil. That is, if the soil is of such a character that it will absorb water, we can figure on smaller pipe; whereas, if it does not absorb water, we should figure on a large pipe.

No. 17. This can be obtained by inquiring of Section Foreman or farmer, also by high water marks on bridge and adjacent land. If high water mark is up or down the stream from the bridge, the fall or rise of the bed of the creek should be given to a point opposite the high water mark.

No. 18. To be determined from previous information and the print showing size of openings. A 48 in. C. I. pipe is the largest pipe that can be used economically. When area demands a larger opening, use a reinforced concrete box. Also a pipe 42 in. in diameter or larger should not be put under a fill above 25 ft. unless you have an extra good foundation. For very large drainage areas, refer the question to the General Office.

No. 19. This information is needed so that the real estate department may look up its records and files.

No. 20. If possible, find how long it may have been used, and if not so used, has it ever been used in the past as an under-crossing or cattle pass.

No. 21. To be obtained from the Real Estate Department by the District Engineer.

No. 22. See the farmer personally as to whether or not he has a contract and whether or not the bridge is used for a cattle pass or overcrossing.

No. 23. If contract is claimed, see what it can be bought for. This should be done while on the ground before it is decided to fill or rebuild and as a guide to assist in reaching a decision.

No. 24. Make detailed estimate of each bridge.

No. 25. This question needs no explanation.

No. 26. Fill out a form for each bridge shown on the list sent and send to the district engineer for examination, who will fill in the recommendation of the engineering department.

No. 27. This is to be answered at a later date when the bridge has been filled or rebuilt.

No. 28. Any general information which you think will be of value in deciding on what should be done.

## GENERAL DIRECTIONS.

Division Engineers should be supplied with blue prints showing the prices of reinforced concrete culverts, of cast iron pipe and of pile bridging; also

blue prints showing the size of openings needed for drainage areas. They should also have a supply of sheets giving the detailed information in regard to bridges.

After the sheets are filled out, they should be sent to the district engineer together with the other reports of the survey. Each sheet should be folded separately in three thicknesses and the number of the bridge and its location lettered upon the back of it.

This report should be accompanied by a detailed estimate for each bridge, both for filling and for rebuilding, and should also be accompanied by a statement in tabulated form of the bridges to be filled or rebuilt. There should be one table for bridges to be filled and charged to repairs, and one for bridges charged to construction. Charges to repairs should be the cost of rebuilding in kind and when cost of rebuilding in kind exceeds the cost of filling and putting in pipe, etc., the entire charge of the bridge should be to repairs. When the cost of filling and putting in pipe exceeds the cost of rebuilding in kind, there will be a charge both to construction and to repairs.

There should be also a third statement showing the bridges to be rebuilt, in which the same details are shown as on these other two sheets.

These tables should be sent in with detailed report, so that they may all be fully considered and any changes made which the General Office may think advisable.

For choosing size of openings asked for in question 18, the drainage diagram shown in Fig. 7 is used for smaller openings; this is based on Fanning's Formula, and while the curves shown are not exactly true they are approximately so.

The upper diagram of "Area for pipes and culverts" is made for a variable velocity of flow through the pipes as shown by the two diagrams at the bottom of the sheet. One of these diagrams showing the variation of the velocity for the size of the opening and the other for the number of acres drained.

In the diagram showing "Area for pipes and culverts" the vertical lines show the number of acres in the drainage area and the horizontal lines show the square feet of waterway while the diagonal lines show the corresponding size of pipe.

In the diagram for "culverts and bridges" the vertical lines show the square miles of drainage area and the horizontal lines the corresponding opening. This diagram is based on a velocity of 8 ft. per second for every size of opening in question and accordingly is not used for the smaller openings where the velocity of flow is less.

These diagrams are supposed to be for average rolling land such as we have in the northern half of Illinois. For other kind of country the size of the opening is varied according to the judgment of the district engineer. In Wisconsin along the river, we would be likely to add to the size of the opening about 15 per cent; southern Illinois deduct about the same amount and in southern Iowa add from 25 to 50 per cent.

For replacing wooden culverts with permanent culverts a form

similar to the one used for filling is used of which the following is a copy:

(Date)..................................

Information required in regard to CULVERT No.......on......

1. Date of Survey.
2. Name of stream, if known.
3. Kind of culvert and size of opening.
4. Number of tracks and centers of same.
5. Height of culvert, bed of stream to base of rail at each track.
6. Length of culvert.
7. Condition of culvert.
8. Can in your opinion, this culvert be channeled out at reasonable cost? If so, or if you are in doubt, report it for special survey.
9. Give high water line below or above top of inside of culvert, and area of cross section of channel below this line.
10. Does high water overflow adjacent property, and if so to what depth, or is it all confined to right-of-way?
11. Give area of adjacent property overflowed; and amount of damage done.
12. Give character of adjacent property. Steep, medium, or flat.
13. How is adjacent property used, and if cultivated what was the character of last crop.
14. Was country on the down stream side of the track overflowed, and if so, to what extent as compared with the upstream side?
15. Can, in your opinion, this culvert be left as it is without damage, or should it be rebuilt, and if so, should it be rebuilt at once, or can it be left until a later date.
16. Width of right-of-way at bridge.
17. Give drainage area, length and width of same, and state whether slope is steep, medium or flat.
18. Character of drainage area; cultivated, timber or pastural.
19. Character of soil.
20. Size and description of pipe or culvert required.
21. Location of culvert with reference to land lines and names of abutting land owners.
22 Is culvert used as under-crossing or cattle pass?
23. Any contract or conditions in deed relating to this?
24. Estimated cost of replacing.
25. Recommendation of Engineering Department.
26. Disposition of Culvert, and when rebuilt.
27. Remarks:

Reports are made up in tabular form on the blank shown, Form 1826. The work of deciding on openings and getting necessary information and then properly using it requires good judgment and it takes considerable time for an engineer to become expert at it so that his judgment is reliable and valuable; and the information taken should be fairly exact. For instance, in some of our earlier surveys one of the engineers used to guess the drainage area. He would stand on the bridge, set down his guess and that of his two chainmen and divide the result by 3. This had the advantage of being a fairly rapid method of doing the work, but one area which he gave in as 100 acres was afterwards found to be 1400 and other results were even worse.

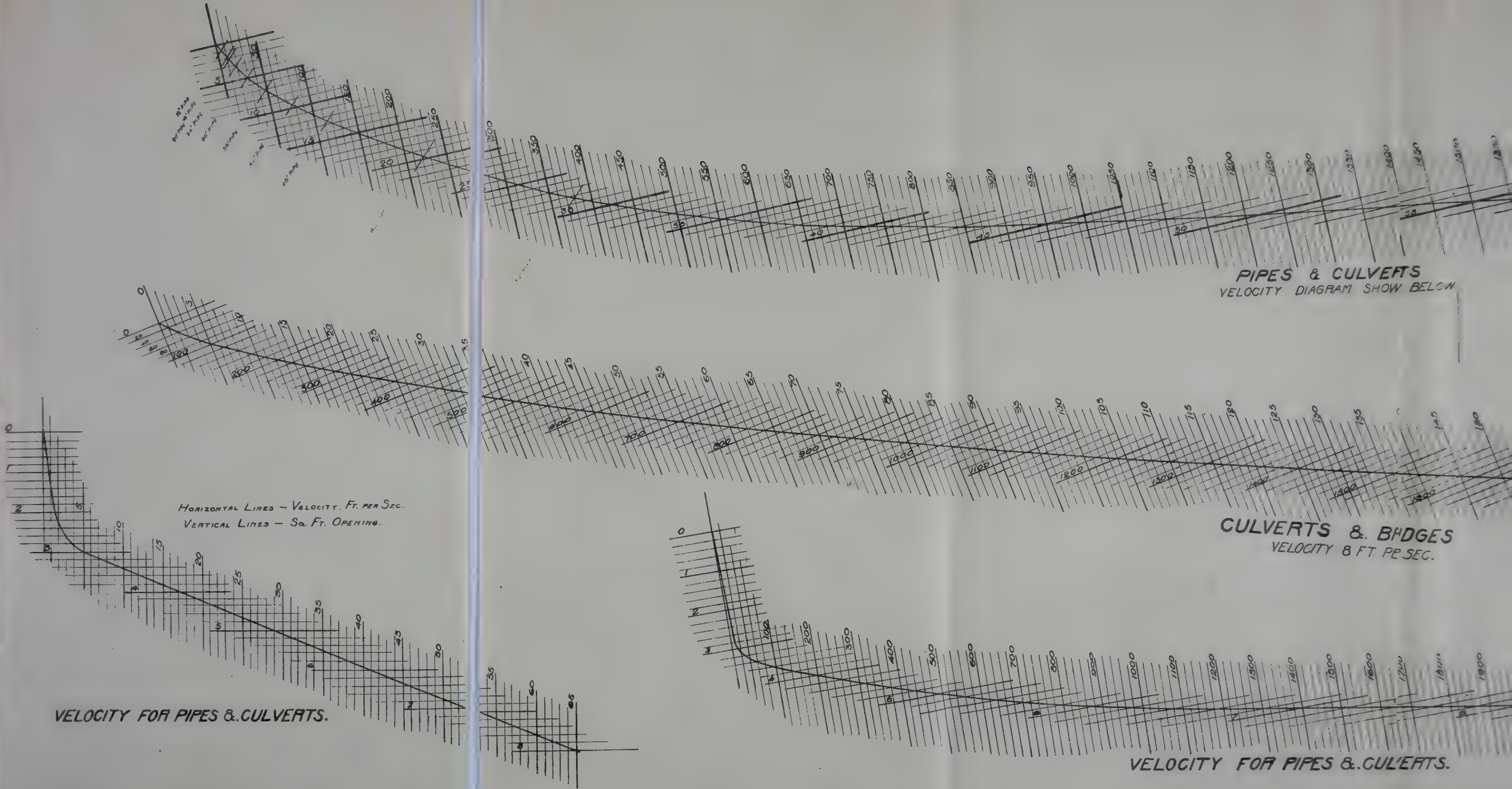
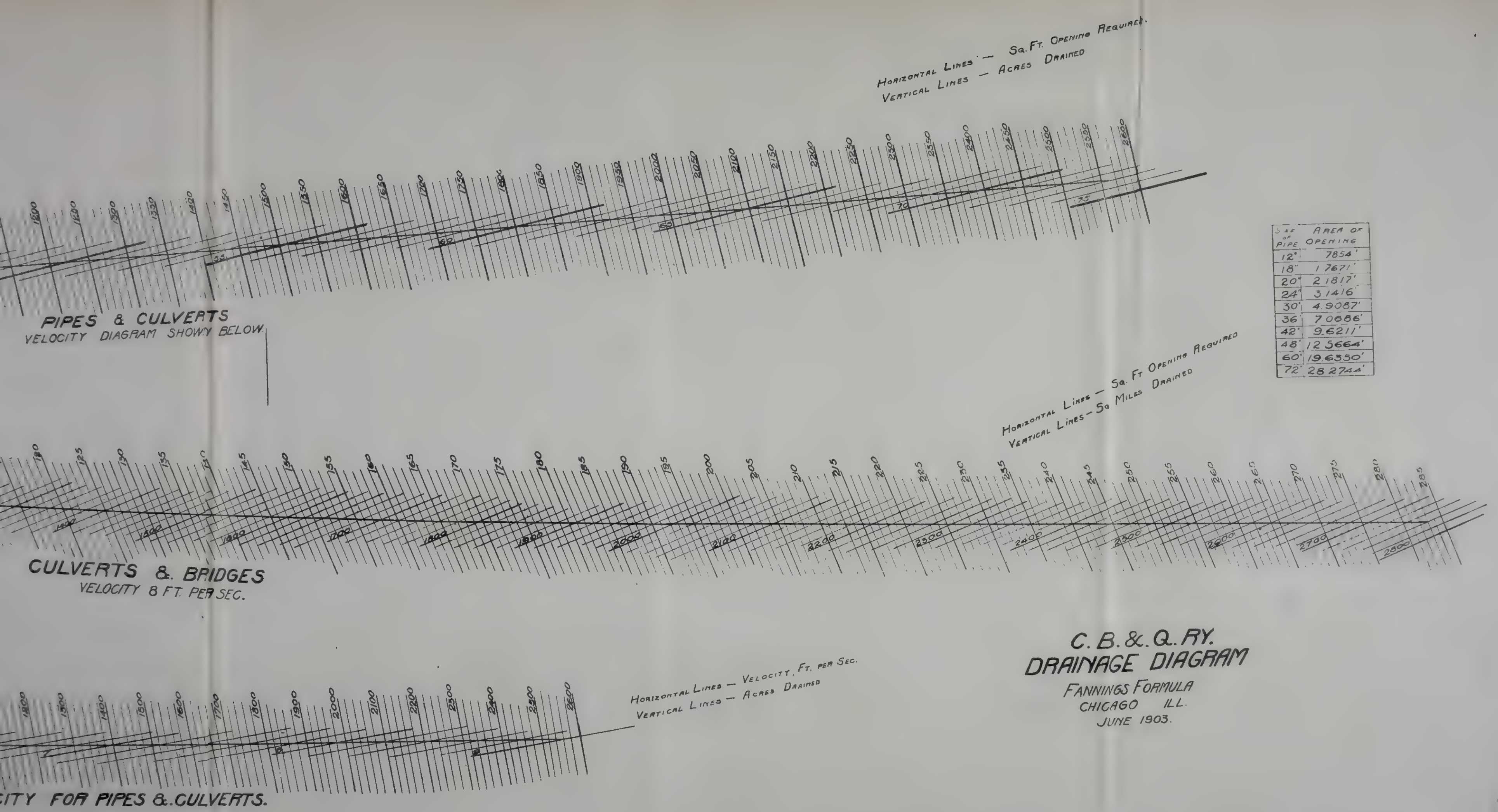

PIPES & CULVERTS
VELOCITY DIAGRAM SHOW BELOW
CULVERTS & BRIDGES
VELOCITY 8 FT. PER SEC.
Horizontal Lines – Velocity. Ft. per Sec.
Vertical Lines – Sq. Ft. Opening.
VELOCITY FOR PIPES & CULVERTS.
VELOCITY FOR PIPES & CULVERTS.

Fig. 7.




| Size of Pipe | Area of Opening |
|---|---|
| 12" | .7854' |
| 18" | 1.7671' |
| 20" | 2.1817' |
| 24" | 3.1416' |
| 30" | 4.9087' |
| 36" | 7.0686' |
| 42" | 9.6211' |
| 48" | 12.5664' |
| 60" | 19.6350' |
| 72" | 28.2744' |

Fig. 7.

H-6-05-200.

Form 1826.

Burlington Route

# Chicago, Burlington & Quincy Railway Company,

.................... District, .................... Division, ....................

## PILE & TRESTLE BRIDGE REPLACEMENT AND RENEWAL FOR 190....

| | No. | Date Built | Av'ge H't. | Max. H't. | Lenght | Drainage | Proposed Opening | | Earth Work Cu. Yds. | Cost of Proposed Work | | | Cost in Kind Charge Repairs | Charges to Construction | Cost to Carry | Years | REMARKS | Disposition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Kind and Size | Length | | Structure | Earth Work | Total | | | | | | |

Form 1826.

With fairly close field work by compass and stepping off distances accompanied by good judgment we get very good results. It is not very often that openings properly chosen are washed out and on the other hand they are not made unreasonably large and expensive. It is bad to make openings too large as well as too small. It frequently is the cause of using temporary structures instead of permanent ones on account of the cost and if permanent structures are made too large it is simply a waste of money.

While the methods above described are by no means perfect they are much better than the old guess method, and it is my hope that this paper may open a discussion which will give us information from which we may make further improvements.

## DISCUSSION.

*Mr. James Dun—* M. W. S. E. —I am handing you herewith a table which has been in use on the Santa Fe System for the past fifteen years for proportioning waterways. In general we have found this table to be sufficient, and particularly up to drainage areas of 5 square miles. In 1903, however, we noted some floods in Central Kansas which exceeded the tables from 200 to 300 per cent. Also in the year 1905 we had a series of floods in the vicinity of Ft. Madison, Iowa, that far exceeded our tables. In one case where the drainage area is about 150 square miles the area of waterway was about 12,000 square feet and the current was so swift as to scour out the stream to a depth of 40 feet. I believe, however, that these floods are rare exceptions and that it would not pay a railway company or any one else to undertake to provide for them.

The table referred to is based upon observations taken by me and others under my jurisdiction on floods in Missouri, Kansas, Indian Territory and Texas. The section of water way at contracted parts of the different streams was accurately measured from time to time as floods occurred and the table was made up from these data. Wherever possible cross sections were taken in the larger streams at points where rock bluffs came in on both sides and where the stream had a rock bottom, thus eliminating the question of scour. This, however, was not practicable in every case.

I am sending you herewith the advance sheets of a publication of the United States Geological Survey in which there appears an article by Mr. E. C. Murphy, who is giving the matter of floods particular attention.

# ATCHISON, TOPEKA & SANTA FE RAILWAY.

## TABLE SHOWING THE APPROXIMATE AREAS OF WATER-WAY FOR VARIOUS DRAINAGE AREAS

| AREAS DRAINED IN SQUARE MILES | AREAS OF WATER-WAY: A MISSOURI & KANSAS | CAST PIPE (Bonds over 15' use 80%) | BOX & ARCH CULVERTS (1st Fig.–Dia. 2nd Fig.–Bench) | PERCENTAGE OF COLUMN "A": ILLINOIS | IND. TER. | TEXAS | NEW MEXICO | SANTA FE PACIFIC | |
|---|---|---|---|---|---|---|---|---|---|
| .01 | 20 | 1–24" | 2×1 B | | | | ↑ | | |
| .02 | 4.0 | 1–24" | 2×2 " | | SOUTH OF PURCELL USE TEXAS COLUMN | | | | |
| .03 | 6.0 | 1–30" | 2×3 " | | | | | | |
| .04 | 7.5 | 1–36" | 2½×3 " | | | | | | |
| .05 | 9.0 | 1–42" | 3×3 " | | | | | | |
| .06 | 10.5 | 1–42" | 3½×3 " | | | | | | |
| .07 | 12.0 | 1–48" | 3×4 " | | | | | | |
| .08 | 135 | 2-36" | 02½×3 " | | | | | | |
| .09 | 15 | 2-36" | " " " " | | | | | | |
| .10 | 16 | 2-36" | " 3×3 " | | | | | | |
| .15 | 25 | 2-48" | " 3×4 " | | | | | | |
| .20 | 32 | 3-42" | 6×4 A | | | | USE COLUMN "A" ↓ | | |
| .25 | 38 | 3-48" | 6×5 " | | | USE COLUMN "A" ↓ | | | |
| .30 | 44 | | 6×5½ " | EAST OF STREATOR USE 60% | | | | | |
| .35 | 51 | | 8×4½ " | | | | | | |
| .40 | 56 | | 8×5 " | | | | | | |
| .45 | 62 | | 8×6 " | | | | | | |
| .50 | 66 | | " " " " | | | | | | |
| .55 | 70 | | 8×6½ " | | | | | | |
| .60 | 74 | | 10×4½ " | | | | | | |
| .65 | 78 | | 10×5 " | | | | | | |
| .70 | 81 | | 10×5½ " | | | | | | |
| .75 | 85 | | 10×6 " | | | | | | |
| .80 | 88 | | 10×6½ " | | | | | | |
| .85 | 91 | | " " " " | | | | | | |
| .90 | 94 | | " " " " | | | | | | |
| 95 | 97 | | 12×5 " | | | | | | |
| 1.0 | 100 | | " " " " | | | | 98½ | | |
| 1.1 | 110 | | 12×6 " | | | 105 | " | | |
| 1.2 | 120 | | 12×7 " | | | " | " | | |
| 1.3 | 130 | | 12×8 " | | | " | " | | |
| 1.4 | 140 | | 14×6½ " | | | " | " | | |
| 1.5 | 150 | | 14×7 " | | | " | " | | |
| 1.6 | 160 | | 16×6½ " | | | " | " | | |
| 1.7 | 170 | | 16×7 " | | | " | " | | |
| 18 | 180 | | 16×7½ " | | NORTH OF PURCELL USE COLUMN "A" | " | " | | |
| 1.9 | 190 | | 16×8 " | | | " | " | | |
| 2 0 | 200 | | 18×7 " | | | " | " | | |
| 2.2 | 220 | | 18×8 " | | | " | " | | |
| 24 | 240 | | 18×9½ " | | | " | " | | |
| 2.6 | 260 | | 20×8 " | | | " | " | | |
| 2.8 | 280 | | 20×9 " | | | " | " | | |
| 3.0 | 300 | | 20×9½ " | | | " | " | | |
| 3.2 | 321 | | 22×8½ " | | | " | " | | |
| 3.4 | 340 | | 22×9 " | | | " | " | | |
| 3.6 | 357 | | 24×8½ " | | | " | " | | |
| 3.8 | 373 | | 24×9 " | WEST OF STREATOR USE 80% | | " | " | | |
| 4.0 | 388 | | 28×7 " | | | " | 97 | | |
| 4.2 | 403 | | 28×7½ " | | | " | " | | |
| 4.4 | 417 | | 28×8 " | | | " | " | | |
| 4.6 | 430 | | 28×8½ " | | | " | " | | |
| 48 | 443 | | 28×9 " | | | " | " | | |
| 5.0 | 455 | | 28×9½ " | | | " | " | | |
| 5.5 | 483 | | 28×10 " | | | " | " | | |
| 6.0 | 509 | | 32×7½ " | | | " | " | | |
| 6.5 | 533 | | 32×8 " | | | " | " | | |
| 7.0 | 556 | | 32×9 " | | | " | " | | |
| 7.5 | 579 | | 32×10 " | | | " | " | | |
| 80 | 601 | | 32×11 " | | | " | " | | |
| 8.5 | 622 | | 32×11½ " | | | " | " | | |
| 9.0 | 641 | | 32×12 " | | | " | 93½ | | |
| 9.5 | 660 | | 32×12½ " | | | " | " | | |
| 10 | 679 | | 32×13 " | | | " | " | | |
| 11 | 710 | | BRIDGES DESIGNED TO PROVIDE AREA ACCORDING TO CIRCUMSTANCES | | | " | " | | |
| 12 | 740 | | | | | " | " | | |
| 13 | 775 | | | | | " | " | | |
| 14 | 805 | | | | | " | " | | |
| 15 | 835 | | | | | " | " | | |
| 16 | 865 | | | | | " | 94 | | |
| 17 | 890 | | | | | " | " | | |
| 18 | 920 | | | | | " | " | | |
| 19 | 945 | | | | | " | " | | |
| 20 | 970 | | | | | " | " | | |
| 22 | 1015 | | | | | " | " | | |

| AREAS DRAINED IN SQUARE MILES | AREAS OF WATER-WAY: A MISSOURI & KANSAS | | | PERCENTAGE OF COLUMN "A": ILLINOIS | IND. TER. | TEXAS | NEW MEXICO | SANTA FE PACIFIC | |
|---|---|---|---|---|---|---|---|---|---|
| 24 | 1060 | | | | | 110 | 94 | | |
| 26 | 1100 | | | | SOUTH OF PURCELL USE TEXAS COLUMN | " | 92 | | |
| 28 | 1140 | | | | | " | " | | |
| 30 | 1180 | BRIDGES TO PROVIDE AREA ACCORDING TO CIRCUMSTANCES | | | | " | " | | |
| 32 | 1220 | | | | | " | " | | |
| 34 | 1255 | | | | | " | " | | |
| 36 | 1290 | | | | | " | 91 | | |
| 38 | 1320 | | | | | " | " | | |
| 40 | 1350 | | | | | " | " | | |
| 45 | 1435 | | | | | " | " | | |
| 50 | 1510 | | | | | " | 89½ | | |
| 55 | 1580 | | | | | 115 | " | | |
| 60 | 1650 | | | | | " | " | | |
| 65 | 1720 | | | EAST OF STREATOR USE 60% | | " | 88 | | |
| 70 | 1780 | | | | | " | " | | |
| 75 | 1840 | | | | | " | " | | |
| 80 | 1900 | | | | | " | 86½ | | |
| 85 | 1960 | | | | | " | " | | |
| 90 | 2015 | | | | | " | " | | |
| 95 | 2065 | | | | | " | " | | |
| 100 | 2120 | | | | | 120 | 85 | | |
| 110 | 2220 | | | | | " | " | | |
| 120 | 2315 | | | | | " | " | | |
| 130 | 2405 | | | | | 125 | 83½ | | |
| 140 | 2500 | | | | | " | " | | |
| 150 | 2580 | | | | | 130 | 82 | | |
| 160 | 2665 | | | | | " | " | | |
| 170 | 2745 | | | | | " | 80½ | | |
| 180 | 2820 | | | | | " | " | | |
| 190 | 2900 | | | | | " | 79 | | |
| 200 | 2970 | | | | | " | " | | |
| 220 | 3115 | | | | | " | 77½ | | |
| 240 | 3245 | | | | | " | " | | |
| 260 | 3370 | | | | | " | 76 | | |
| 280 | 3495 | | | | | " | " | | |
| 300 | 3615 | | | | | " | 74½ | | |
| 325 | 3770 | | | | | " | " | | |
| 350 | 3900 | | | | | " | 73 | | |
| 375 | 4035 | | | | | " | " | | |
| 400 | 4165 | | | | | " | 71½ | | |
| 450 | 4385 | | | | | " | 70 | | |
| 500 | 4610 | | | | | " | 68½ | | |
| 550 | 4825 | | | | | " | 67 | | |
| 600 | 5030 | | | | NORTH OF PURCELL USE COLUMN "A" | " | 65½ | | |
| 650 | 5230 | | | WEST OF STREATOR USE 80% | | " | 64 | | |
| 700 | 5420 | | | | | " | 62½ | | |
| 750 | 5610 | | | | | " | 61 | | |
| 800 | 5800 | | | | | " | 59½ | | |
| 850 | 5890 | | | | | " | 58 | | |
| 900 | 6080 | | | | | " | 56½ | | |
| 950 | 6230 | | | | | " | | | |
| 1000 | 6380 | | | | | " | | | |
| 1100 | 6705 | | | | | " | | | |
| 1200 | 6960 | | | | | " | | | |
| 1300 | 7230 | | | | | " | | | |
| 1400 | 7480 | | | | | " | | | |
| 1500 | 7725 | | | | | " | | | |
| 1600 | 7960 | | | | | " | | | |
| 1700 | 8195 | | | | | " | | | |
| 1800 | 8390 | | | | | " | | | |
| 1900 | 8625 | | | | | " | | | |
| 2000 | 8820 | | | | | " | | | |
| 2200 | 9240 | | | | | " | | | |
| 2400 | 9605 | | | | | " | | | |
| 2600 | 9970 | | | | | " | | | |
| 2800 | 10320 | | | | | " | | | |
| 3000 | 10640 | | | | | " | | | |
| 3500 | 11445 | | | | | " | | | |
| 4000 | 12160 | | | | | " | | | |
| 4500 | 12825 | | | | | " | | | |
| 5000 | 13500 | | | | | " | | | |
| 5500 | 14080 | | | | | " | | | |
| 6000 | 14520 | | | | | " | | | |
| 6500 | 15140 | | | | | " | | | |

The above classification by states is for convenience only, and merely denotes the general characteristics of topography and rainfall.

Column "A" in this table is prepared from observations of streams in Southwest Missouri, Eastern Kansas, Western Arkansas and the Southeastern portions of the Indian Territory, in all of this region steep rocky slopes prevail and the soil absorbs but a small percentage of the rainfalls, it indicates larger water-ways than are required in Western Kansas and level portions of Missouri, Colorado, New Mexico and Western Texas —

Fig. 8.

With fair
tances accon
It is not ver
and on the
expensive.
small. It f
instead of p
structures a
While the
are much be
this paper
from which

*Mr. Jam*
a table whi
fifteen year
found this
areas of 5
in Central
per cent.
the vicinity
In one case
area of w
was so sw
believe, ho
would not
provide fo
The tabl
others und
Territory
parts of t
to time as
data. Wl
streams a
where the
of scour.
I am s
of the Ur
article by
particular

Your attention is invited to the flood rate per square mile, pages 184 to 189, and to the proposed method of computing formula for maximum discharge, pages 189 to 190. The value of "q" as given on page 190 is referred to in my letter in reply to Mr. Murphy, copy of which I also send herewith.

CHICAGO, Ill., Dec. 18th, 1905.

*Mr. E. C. Murphy, Engineer, Department of the Interior, U. S. Geological Survey, Washington, D. C.*

Dear Sir: Replying to your favor of December 12th transmitting copy of report on destructive floods in the United States in 1904.

I do not know of anything to suggest in addition to your valuable paper except that on table on page 184 you give the maximum rate of flood in, I presume, second feet per square mile. This is not stated, however, in the table.

The maximum rate of discharge of streams in southeast United States, states that it is in second feet per square mile. Comparing your results from table on page 190 I find the second feet per square mile is considerably less than I have estimated by my tables, in which I assume that the velocity under bridges in flood times would be an average of 10 ft. per second.

The enclosed table shows velocities in second feet per square mile of your tables and mine.

| Drainage rrea in square miles. | Second feet per square mile, by Dun's table. | Second feet per square mile by Murphy's table Page 190. |
|---|---|---|
| 10,000 | 18.4 | 19.5 |
| 7,000 | 22.3 | 21.4 |
| 5,000 | 27.0 | 24.0 |
| 4,000 | 30.4 | 26.0 |
| 3,000 | 35.4 | 29.0 |
| 2,000 | 44.1 | 35.0 |
| 1,000 | 63.8 | 51.0 |
| 750 | 74.8 | 59.0 |
| 500 | 92.2 | 72.0 |
| 250 | 132.4 | 95.0 |
| 100 | 212.0 | 126.0 |
| 50 | 302.0 | 142.0 |
| 20 | 485.0 | 153.0 |
| 10 | 679.0 | 157.0 |
| 5 | 910.0 | 159.0 |
| 1 | 1,000.0 | 161.0 |

You will note from the above that there is a great discrepancy in the smaller areas, and I am compelled to think that your values of "q" in table on page 190 are much too small for small areas. Even multiplying the drainage areas as used on this rate by 5 ft. per second, or, half of the above amount, would give 500 second-feet on one square mile as against 161 given by you.

We have abundant evidence from numerous culverts that tables are none too large, and in cases from 100 to 10 square miles have found a number of instances where the waterways provided were not nearly large enough.

Yours very truly,

(Signed) JAMES DUN,
*Chief Engineer System.*

## A METHOD OF COMPUTING CROSS-SECTION AREA OF WATERWAYS.

By E. C. Murphy.

The proper size of channel cross section of a stream depends mainly on the rate of flow of the stream. The method proposed in this paper for finding cross-section area is based on the fundamental formula that $F = \frac{Q}{V}$, where $F$ is the cross-section area of the stream, $Q$ the maximum discharge in cubic feet per second, and $V$ is the velocity of the maximum discharge in the channel.

The formulæ in common use for this purpose generally have the form $F = CM^k$, in which $F$ is the cross-section area in square feet, $M$ is the drainage area in square miles or acres, $C$ is a quantity whose value depends on the character of the country, and $^k$ is a fraction generally less than unity; e. g., the formula used by the engineers of the Missouri Pacific Railway Company is $F = 0.25\ M$ to $0.17\ M$. The proposed method is based on measurements of the flood flow of streams and on the observed maximum range of stage and slope of each particular stream.

### FACTORS DETERMINING MAXIMUM DISCHARGE.

The maximum discharge of a stream depends on several quantities. Primarily it is dependent on—

(1) Extent, duration, and intensity of precipitation, especially the latter in the case of small drainage basins.

(2) Direction of motion of the storm causing the flood. If the storm moves in the direction of flow of the stream the intensity of flood will be greater than if it moves in the opposite direction or across it.

(3) The amount of snow on the ground and the temperature during the storm. Large floods are often due largely to melting snow when the ground is frozen, and in such cases the run-off is much larger than the rainfall.

(4) The storage, both natural and artificial, in the drainage basin. Storage spreads the flood over a larger period and thus reduces the maximum rate of flow.

(5) The size of the drainage basin. Rain storms of great intensity generally cover a comparatively small area, and a larger part of a small drainage basin is more likely to be covered by a very intense storm than of a larger basin. The maximum discharge per square mile will, therefore, increase as the size of the drainage basin decreases.

(6) The physiography of the drainage basin. The maximum rate of flow from a comparatively long and narrow drainage basin, with tributaries entering a considerable distance apart, will be less than from a basin of nearly circular shape of the same size, but with the tributaries entering the main stream in close proximity. Steep, impervious, deforested slopes of drainage basin, steep slope of bed of tributaries, and small slope of main stream intensify flood flow.

Among the more or less artificial conditions that increase the flow may be mentioned controlled storage in the basin; deforestation and cultivation; reduction in width of channel by placing abutments of bridges in the stream; the use of piers that prevent scour of bed, collect drift, and hold back a part of the flow for a time, causing a greatly increased flood wave; the formation of ice gorges; and the failure of dams and reservoir walls.

Freshets occur on all streams, usually once a year, sometimes two or more times a year; great floods that result from natural causes occur at irregular intervals, varying from a few years to many years apart. It is impossible to predict the time of their occurrence or determine whether the largest recorded flood is the largest that will ever occur.

It is very difficult to measure the discharge of a stream at maximum stage with accuracy. At such a time the stream usually carries much drift, overflows its banks, and changes its stage rapidly, all of which make accurate measurement of flow difficult.

## MAXIMUM RATE OF DISCHARGE.

It may be seen, from the foregoing and other facts that might be cited, that the rate of flood discharge of streams in different drainage basins will differ by a considerable amount. The difficulty of measuring the rate of flow of any flood and the uncertainty whether any flood will be the greatest that will ever occur on that stream are both

so great that it is useless to attempt to figure closely the maximum rate of flow. It will suffice, therefore, to divide the country into six or eight parts, according to the topography and rainfall, and to obtain a relation between rate of flow and size of drainage basin for each. The tables below give the maximum rate of flow per square mile from drainage basins in various parts of the United States, the drainage area in square miles above the point of measurement, and the date of flood. It is impossible to give, except in a very few cases, the duration of the maximum rate of flow. In some cases the duration was probably not more than half an hour; in other cases the maximum rate given is the mean for several hours, and possibly for twenty-four hours of the day when the flow was greatest. It is assumed that the maximum rate given is for a period of less than twenty-four hours, unless otherwise stated.

These data are selected from a large mass of flood-flow records and are the largest rates of flow that appear to be fairly reliable that the author has seen. Some of these were obtained from careful weir measurements, while others are rough estimates.

*Maximum rate of discharge of streams in northeastern United States.*

[In second-feet per square mile.]

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Budlong Creek, Utica, N. Y | 1.13 | Mar. 25, 1904 | 120.40 | U. S. Geol. Sur. W. S. P. No. 147. |
| Sylvan Glen Creek, New Hartford, N. Y. | 1.18 | do | 56.58 | Do. |
| Pequest River, Hunts Pond, N. J. | 1.70 | | 25.30 | N. J. Geol. Sur., 1894, pt. 4. |
| Starch Factory Creek, New Hartford, N. Y. | 3.40 | Mar. 25, 1904 | 109.62 | U. S. Geol. Sur. W. S. P. No. 147. |
| Reels Creek, Deerfield, N. Y | 4.40 | Mar. 26, 1904 | 48.36 | Do. |
| Skinner Creek, Mannsville, N. Y. | 6.40 | —— —, 1891 | 124.20 | U. S. B. Engrs. D. W., 1899. |
| Coldspring Brook, Mass | 6.43 | Feb. —, 1886 | 48.40 | Trans. Am. Soc. C. E., vol. 25. |
| Croton River, South Branch, N. Y. | 7.80 | —— —, 1869 | 73.90 | Trans. Am. Soc. C. E., vol. 4. |
| Woodhull Reservoir, Herkimer, N. Y. | 9.40 | —— —, 1869 | 77.80 | Do. |
| Stony Brook, Boston, Mass | 12.7 | | 121.00 | Report of Stony Brook Flood Com. |
| Great River, Westfield, Mass | 14.0 | | [a]71.40 | Report of H. F. Mills. |
| Smartswood Lake, N. J | 16.0 | | 68.00 | N. J. Geol. Sur., 1894, pt. 4. |
| Williamstown River, Williamstown, Mass. | 16.5 | | 34.00 | U. S. B. Engrs. D. W., 1899. |
| Croton River, West Branch, N. Y. | 20.5 | Jan. —, 1874 | 54.40 | E. M. Treman. |
| Beaverdam Creek, Altmar, N. Y. | 20.7 | | 111.00 | U. S. B. Engrs. D. W., 1899. |
| Trout Brook, Centerville, N. Y. | 23.0 | | 50.60 | Do. |
| Wantuppa Lake, Fall River, Mass. | 28.5 | —— —, 1875 | 72.00 | Trans. Am. Soc. C. E., vol. 4. |
| Pequest River, Huntsville, N. J. | 31.4 | | 19.30 | N. J. Geol. Sur., 1894, pt. 3. |
| Sawkill, near mouth, N. J | 35.0 | | 228.60 | U. S. Geol. Sur. W. S. P. No. 35. |

[a] Average flow for day of maximum discharge.

*Maximum rate of discharge of streams in northeastern United States*—Cont'd.

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Whippany River, Whippany, N. J. | 37.0 | Oct. —, 1903 | 61.62 | U. S. Geol. Sur. (unpublished) |
| Cuyadutta Creek, Johnstown, N. Y. | 40.0 | — —, 1896 | 72.40 | U. S. B. Engrs. D. W., 1899. |
| West Canada Creek, Motts Dam, N. Y. | 47.5 | .............. | 34.10 | Do. |
| Sanquoit, New York Mills, N. Y. | 51.5 | .............. | 53.40 | Do. |
| Rockaway River, Dover, N. J. | 52.5 | .............. | 43.00 | N. J. Geol. Sur., 1894. |
| Oneida Creek, Kenwood, N. Y. | 59.0 | — —, 1890 | 41.20 | U. S. B. Engrs. D. W., 1899. |
| Flat River, R. I. | 61.0 | Mar. —, 1843 | 120.00 | Trans. Am. Soc. C. E., vol. 4. |
| Camden Creek, Camden, N. Y. | 61.4 | June —, 1889 | 24.10 | U. S. B. Engrs. D. W., 1899. |
| Nine Mile Creek, Stittville, N. Y. | 62.6 | Aug. —, 1898 | 124.90 | Do. |
| Wissahickon Creek, Philadelphia, Pa. | 64.6 | — —, 1898 | 43.50 | U. S. Geol. Sur., 20 An., pt. 4. |
| Sandy Creek, Allendale, N. Y. | 68.4 | — —, 1891 | 87.70 | U. S. B. Engrs. D. W., 1899. |
| Rock Creek, Washington, D. C. | 77.5 | .............. | 126.30 | Tech. Quar. Mass. Inst. 1891. |
| Sudbury River, Farmington, Mass. | 78.0 | — —, 1897 | 41.38 | Ch. engr. water dept. N. Y. City. |
| Pequanock River, Pompton, N. J. | 78.0 | Mar. —, 1902 | 55.78 | U. S. Geol. Sur. (unpublished). |
| Hockanum River, Conn. | 79.0 | .............. | 78.10 | Ch. U. S. Engr. Corps, 1878. |
| Nashua River, Mass. | 84.5 | — —, 1850 | 71.04 | Trans. Am. Soc. C. E., vol. 4. |
| Independence Creek, Crandall, N. Y. | 93.2 | Apr. —, 1869 | 66.50 | Black River Water Claims, vol. 1. (unpublished). |
| Passaic River, Chatham, N. J. | 100 | Oct. 11, 1903 | 17.20 | U. S. Geol. Sur. (unpublished). |
| Deer River, Deer River, N. Y. | 101 | Apr. —, 1869 | 78.10 | U. S. B. Engrs. D. W., 1899. |
| Wanaque River, N. J. | 101 | Sept. —, 1882 | 66.00 | N. J. Geol. Sur., 1894. |
| Tohickon Creek, Mount Pleasant, Pa. | 102 | — —, 1885 | 112.50 | Rept. Phila. water board. |
| Fish Creek, East Branch, Point Rocks, N. Y. | 104 | — —, 1897 | 80.50 | U. S. B. Engrs. D. W., 1899. |
| Nashua River, Mass. | 109 | — —, 1848 | 104.53 | Trans. Am. Soc. C. E., vol. 4. |
| Sandy Creek, North Branch, Adams, N. Y. | 110 | — —, 1897 | 67.30 | U. S. B. Engrs. D. W., 1899. |
| Scantic River, North Branch, Conn. | 118 | .............. | 51.80 | Ch. U. S. Engr. Corps, 1878. |
| Ramapo River, Mahwah, N. J. | 118 | Oct. —, 1903 | 105.09 | U. S. Geol. Sur. (unpublished). |
| Rockaway River, Boonton, N. J. | 125 | Mar. 2, 1902 | 22.24 | Do. |
| Patuxent River, Laurel, Md. | 137 | — —, 1897 | 31.20 | U. S. Geol. Sur., 19 An., pt. 4. |
| Neshaminy Creek, below forks, Pa. | 139 | — —, 1894 | 97.60 | Eng. News, May, 1893. |
| Oriskany Creek, Colemans, N. Y. | 141 | — —, 1888 | 55.80 | U. S. B. Engrs. D. W., 1899. |
| Oriskany Creek, Oriskany, N. Y. | 144 | Mar. 25, 1904 | 29.00 | U. S. Geol. Sur. W. S. P. No. 147. |
| Perkiomen Creek, Frederick, Pa. | 152 | — —, 1889 | 69.20 | Rept. Phila. water board. |
| Mohawk River, Ridge Mills, N. Y. | 153 | .............. | 46.40 | U. S. B. Engrs. D. W., 1899. |
| Mohawk River, State dam, Rome, N. Y. | 158 | Mar. 26, 1904 | 27.34 | U. S. Geol. Sur. W. S. P. No. 147. |
| Ramapo River, Pompton, N. J. | 160 | — —, 1882 | 56.10 | N. J. Geol. Sur., 1894. |
| Fish Creek, West Branch, McConnellsville, N. Y. | 187 | — —, 1885 | 32.70 | U. S. B. Engrs. D. W., 1899. |
| Salmon River, Altmar, N. Y. | 221 | .............. | 27.60 | Do. |
| Black River, Forestport, N. Y. | 268 | .............. | 39.00 | Do. |
| Croton River, Croton Dam, N. Y. | 339 | .............. | 74.90 | Trans. Am. Soc. C. E., vol. 4. |

*Maximum rate of discharge of streams in northeastern United States*—Cont'd.

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Great River, Westfield, Mass | 350 | .............. | [a]151.40 | H. F. Mills. |
| East Canada Creek, Dolgeville, N. Y. | 356 | Aug. —, 1898 | 24.70 | U. S. B. Engrs. D. W., 1899. |
| Moose River, Ayers mill, N. Y | 407 | .............. | 31.00 | Black River Water Claims Com., vol. 1. |
| Stony Creek, Johnstown, Pa | 428 | .............. | 70.00 | J. J. R. Croes. |
| West Canada Creek, Middleville, N. Y. | 518 | Aug. —, 1898 | 24.90 | U. S. B. Engrs. D. W., 1899. |
| Farmington River, Conn | 584 | .............. | 41.70 | Ch. U. S. Engr. Corps, 1878. |
| Monocacy River, Frederick, Md. | 665 | —— —, 1898 | 29.80 | U. S. Geol. Sur., 20 An. |
| Passaic River, Little Falls, N. J. | 773 | Sept. —, 1882 | 24.20 | N. J. Geol. Sur. 1894, pt. 3. |
| North River, Port Republic, Va. | 804 | —— —, 1896 | 29.80 | U. S. Geol. Sur., 20 An. |
| Passaic River, Dundee, N. J | 828 | Oct. 10, 1903 | 43.38 | W. S. and I. P. No. 92. |
| North River, Glasgow, Va | 831 | —— —, 1896 | 44.80 | U. S. Geol. Sur., 20 An. |
| Raritan River, Boundbrook, N. J. | 879 | —— —, 1882 | 59.30 | N. J. Geol Sur., 1894, pt. 3. |
| Potomac, north branch, Cumberland, Md. | 891 | —— —, 1897 | 22.80 | U. S. Geol. Sur., 19 An. |
| Black River, Lyons Falls, N. Y. | 897 | Apr. —, 1869 | 46.00 | U. S. B. Engrs. D. W., 1899. |
| Schoharie Creek, Fort Hunter, N. Y. | 948 | —— —, 1892 | 44.00 | Do. |
| Genesee River, Mount Morris, N. Y. | 1,070 | 1894–1896 | 39.20 | U. S. Geol. Sur., 20 An. |
| Mohawk River, Little Falls, N. Y. | 1,306 | Mar. 2, 1902 | 21.83 | U. S. Geol. Sur. W. S. P. No. 147. |
| Greenbrier River, Alderson, W. Va. | 1,344 | —— —, 1897 | 41.60 | U. S. Geol. Sur., 19 An. |
| Black River, Carthage, N. Y | 1,812 | Apr. —, 1869 | 21.20 | U. S. B. Engrs. D. W., 1899. |
| Schuylkill River, Fairmount, Pa. | 1,915 | —— —, 1898 | 12.20 | U. S. Geol. Sur., 20 An. |
| Chemung River, Elmira, N. Y. | 2,055 | June —, 1889 | 67.10 | Rept. of F. Collingswood to city, 1889. |
| James River, Buchanan, Va | 2,058 | —— —, 1896 | 15.60 | U. S. Geol. Sur., 19 An. |
| Androscoggin River, Rumford, Me. | 2,220 | —— —, 1869 | 25.00 | U. S. Geol. Sur., 20 An. |
| Genesee River, Rochester, N. Y. | 2,365 | Mar. —, 1865 | 17.00 | U. S. B. Engrs. D. W, 1899. |
| Hudson River, Fort Edward, N. Y. | 2,825 | Apr. —, 1900 | 15.60 | Rept. E. A. Bond, State engr., 1900. |
| Shenandoah River, Millville, W. Va. | 2,995 | —— —, 1898 | 11.40 | U. S. Geol. Sur., 19 An. |
| Mohawk River, Rexford, N. Y. | 3,384 | —— —, 1892 | 23.10 | U. S. B. Engrs. D. W., 1899. |
| Merrimac River, Lowell, Mass. | 4,085 | —— —, —— | 19.80 | N. J. Geol. Sur., 1894, pt. 3. |
| Kennebec River, Waterville, Me. | 4,410 | —— —, 1896 | 25.20 | U. S. Geol. Sur., 19 An. |
| Susquehanna, west branch, Williamsport, Pa. | 4,500 | .............. | 11.60 | Eng. News, Feb. 14, 1891. |
| Hudson River, Mechanicsville, N. Y. | 4,500 | —— —, 1869 | 15.50 | U. S. Geol. Sur., 19 An. |
| Merrimac River, Lawrence, Mass. | 4,553 | .............. | 23.40 | Do. |
| Potomac River, Dam No. 5, Md. | 4,640 | .............. | 22.20 | N. J. Geol. Sur., 1894, pt. 4. |
| Delaware River, Lambertville, N. J. | 6,500 | .............. | 53.80 | Trans. Am. Soc. C. E., vol. 10. |
| Delaware River, N. J | 6,750 | .............. | 50.00 | Do. |
| Delaware River, Stockton, N. J. | 6,790 | —— —, 1841 | 37.50 | N. J. Geol. Sur., 1894, pt. 3. |
| Susquehanna River, Northumberland, Pa. | 6,800 | —— —, 1889 | 17.50 | Eng. News, Feb. 14, 1891. |

[a] Average flow for day of maximum discharge.

*Maximum rate of discharge of streams in northeastern United States*—Cont'd.

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Connecticut River, Holyoke, Mass. | 8,660 | May —, 1854 | 21.10 | Ch. U. S. Engr. Corps, 1878. |
| Potomac River, Point of Rocks, Md. | 9,654 | —— —, 1897 | 19.40 | U. S. Geol. Sur., 19 An. |
| Connecticut River, Hartford, Conn. | 10,234 | .............. | 20.30 | Trans. Am. Soc. C. E., vol. 7. |
| Potomac River, Md ............ | 11,043 | .............. | 42.60 | Eng. News, May 25, 1893. |
| Potomac River, Great Falls, Md. | 11,427 | —— —, 1889 | 41.20 | U. S. Geol. Sur., 14 An. |
| Potomac River, Chain Bridge, D. C. | 11,545 | —— —, 1893 | 17.20 | Do. |
| Susquehanna River, Harrisburg, Pa. | 24,030 | —— —, 1894 | 18.90 | U. S. Geol. Sur., 18 An. |

*Maximum rate of discharge of streams in southeastern United States.*

[In second-feet per square mile.]

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Coosawattee River, Carters, Ga. | 532 | May 21, 1901 | 31.86 | U. S. Geol. Sur. W. S. P. No. 75. |
| Etowah River, Canton, Ga .... | 604 | Jan. —, 1895 | 31.50 | U. S. Geol. Sur., 18 An. |
| Tuckasegee River, Bryson, N. C. | 662 | Mar. 19, 1899 | 58.23 | U. S. Geol. Sur., 21 An. |
| Little Tennessee River, Judson, N. C. | 675 | Dec. 29, 1901 | 85.24 | U. S. Geol. Sur. W. S. P. No. 75. |
| Broad River, Carlton, Ga ...... | 762 | Feb. 2, 1902 | 38.22 | U. S. Geol. Sur. W. S. P. No. 83. |
| Saluda River, Waterloo, S. C .. | 1,056 | June 8, 1903 | 18.00 | U. S. Geol. Sur. W. S. P. No. 98. |
| Catawba River, Catawba, N. C. | 1,535 | May 29, 1901 | 53.10 | U. S. Geol. Sur. W. S. P. No. 75. |
| Chattahoochee River, Oakdale, Ga. | 1,560 | Feb. 27, 1899 | 27.92 | U. S. Geol. Sur., 21 An. |
| Ocmulgee River, Macon, Ga... | 2,425 | Mar. 1, 1902 | 20.97 | U. S. Geol. Sur. W. S. P. No. 83. |
| Yadkin River, Salisbury, N. C. | 3,399 | Mar. —, 1899 | 31.60 | U. S. Geol. Sur., 21 An. |
| Tallapoosa River, Milstead, Ala. | 3,840 | Dec. 30, 1901 | 18.23 | U. S. Geol. Sur. W. S. P. No. 75. |
| Coosa River, Rome, Ga ........ | 4,001 | Dec. 31, 1901 | 16.04 | Do. |
| Broad River, Alston, S. C...... | 4,609 | May 23, 1901 | 28.44 | Do. |
| Black Warrior River, Tuscaloosa, Ala. | 4,900 | Apr. 18, 1900 | 27.89 | U. S. Geol. Sur., 22 An. |
| New River, Fayette, W. Va.... | 6,200 | Mar. 4, 1899 | 17.83 | Do. |
| Coosa River, Riverside, Ala ... | 6,850 | Oct. 8, 1898 | 10.53 | U. S. Geol. Sur., 20 An. |
| Savannah River, Augusta, Ga. | 7,294 | Sept. —, 1888 | a 42.50 | U. S. Geol. Sur., 14 An. |
| Tennessee River, Chattanooga, Tenn. | 21,418 | Apr. —, 1896 | 20.80 | U. S. Geol. Sur., 19 An. |

*Maximum rate of discharge of streams in central United States.*

[In second-feet per square mile.]

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Des Plaines River, Riverside, Ill. | 630 | June —, 1892 | [a]9.05 | U. S. Geol. Sur., 20 An. |
| Verdigris River, Liberty, Kans. | 3,067 | July 8, 1904 | 16.43 | U. S. Geol. Sur. W. S. P. No. 147. |
| Neosho River, Iola, Kans | 3,670 | July 10, 1904 | 20.33 | Do. |
| Grand River, Grand Rapids, Mich. | 4,900 | Mar. 27, 1904 | [a]8.04 | Do. |
| Smoky Hill River, Ellsworth, Kans. | 7,980 | May 29, 1903 | [a]1.43 | W. S. and I. P. No. 96. |
| Kanawha River, Charleston, W. Va. | 8,900 | Aug. —, 1875 | 13.50 | Eng. News, May 25, 1893. |
| Blue River, Manhattan, Kans. | 9,490 | May 31, 1903 | [a]7.25 | W. S. and I. P. No. 96. |
| Republican River, Junction, Kans. | 25,837 | do | [a]1.80 | Do. |
| Mississippi River, St. Paul, Minn. | 36,085 | Apr. —, 1897 | 19.70 | U. S. Geol. Sur., 19 An. |
| Kansas River, Lecompton, Kans. | 58,550 | May 31, 1903 | 3.98 | W. S. and I. P. No. 96. |

[a] Average flow for day of maximum discharge.

*Maximum rate of discharge of streams in southwestern United States.*

[In second-feet per square mile.]

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Gallinas River, Las Vegas, N. Mex. | 90 | Sept. 30, 1904 | 129.10 | U. S. Geol. Sur. W. S. P. No. 147. |
| Mora River, La Cueva, N. Mex. | 159 | Sept. 29, 1904 | 139.70 | Do. |
| Cherry Creek, Colo. | 175 | | 57.00 | W. S. and I. P. No. 81. |
| Rapid Creek, Rapid City, S. Dak. | 320 | June 6, 1904 | 2.85 | U. S. Geol. Sur. W. S. P. No. 147. |
| Salt Creek, at mouth, N. Mex. | 3,052 | Oct. —, 1904 | 4.10 | Do. |
| Hondo River reservoir, N. Mex | 1,387 | do | 4.56 | Do. |
| Canadian River, Logan, N. Mex | 11,440 | do | [a]12.29 | Do. |
| Canadian River, Taylor, N. Mex | 2,832 | do | [b]32.11 | Do. |
| Canadian River, French, N. Mex. | 1,478 | do | [c]105.56 | Do. |
| Pecos River, Fort Sumner, N. Mex. | 6,191 | do | 7.29 | Do. |
| Pecos River, Roswell, N. Mex. | 14,840 | do | 3.75 | Do. |
| Redwater River, Belle Fourche, S. Dak. | 1,006 | June 5, 1904 | 8.00 | Do. |
| Sapello River, Los Alamos, N. Mex. | 221 | Sept. —, 1904 | 36.7 | Do. |
| Purgatory River, Trinidad, Colo. | 742 | Sept. 30, 1904 | 61.2 | Do. |
| Salt River, Roosevelt, Ariz. | 5,756 | Mar. —, 1893 | 36.0 | U. S. Geol. Sur. W. S. P. No. 73. |
| Verde River, McDowell, Ariz. | 6,000 | do | [d]24.05 | Do. |
| Salt River, Ariz | 12,000 | Feb. —, 1891 | 24.69 | U. S. Geol. Sur. W. S. P. No. 81. |
| Gila River, Florence, Ariz. | 17,750 | Feb. 17, 1891 | 7.50 | Do. |
| Pecos River, Santa Rosa, N. Mex. | 2,649 | Sept. 30, 1904 | 17.56 | U. S. Geol. Sur. W. S. P. No. 147. |
| Mora River, Weber, N. Mex. | 422 | do | 65.70 | Do. |
| Rio Grande, Rio Grande, N. Mex. | 11,250 | Oct. —, 1904 | 2.75 | Do. |

[a] Rate for 12 hours. [b] Rate for 7 hours. [c] Rate for 0.5 hour. [d] Rate for 24 hours.

*Maximum rate of discharge of streams in California.*

[In second-feet per square mile.]

| Stream and place. | Drainage area, in square miles. | Date. | Maximum rate. | Authority. |
|---|---|---|---|---|
| Mormon Canyon, Los Angeles, Cal. | 15.5 | ............... | 48.5 | U. S. Geol. Sur. W. S. P. No. 81. |
| Yuba River, Bowman Dam, Cal. | 19 | ............... | 31.6 | Do. |
| Sweetwater River, Sweetwater Dam, Cal. | 186 | Jan. —, 1895 | 97.5 | Do. |
| Tuolumne River, Lagrange, Cal. | 1,501 | ............... | 30.6 | Do. |
| San Joaquin River, Hamptonville, Cal. | 1,637 | Jan. —, 1881 | [a]36.51 | Do. |
| Kings River, State Point, Cal.. | 1,742 | Jan. —, 1901 | [a]25.22 | Do. |
| Kern River, Rio Bravo, Cal.... | 2,345 | May —, 1897 | [a]2.3 | Do. |
| Sacramento River, Iron Canyon, Cal. | 9,295 | Feb. —, 1904 | 23.47 | U. S. Geol. Sur. W. S. P. No. 147. |
| Yuba River, Smartsville, Cal.. | 1,220 | .....do....... | [a]49.02 | Do. |
| Feather River, Oroville, Cal... | 3,350 | .....do....... | [a]31.49 | Do. |
| Stony River, Fruto, Cal......... | 760 | Mar. —, 1904 | [a]29.21 | Do. |

[a] Mean for day when discharge was a maximum.

## FORMULAS FOR MAXIMUM DISCHARGE AND AREA OF CROSS SECTION.

Some of the data for streams in the northeastern United States are plotted in fig. 19, using the areas of drainage basin in square miles as abscissæ and the maximum rates of flow as ordinates. The curve A B, whose equation is

$$q=\frac{46{,}790}{M+320}+15,$$

has been drawn to represent the relation between rate of flow and size of drainage basin for this section of the country. In this equation, $M$ is the drainage area in square miles and $q$ the maximum discharge in cubic feet per second per square mile of drainage.

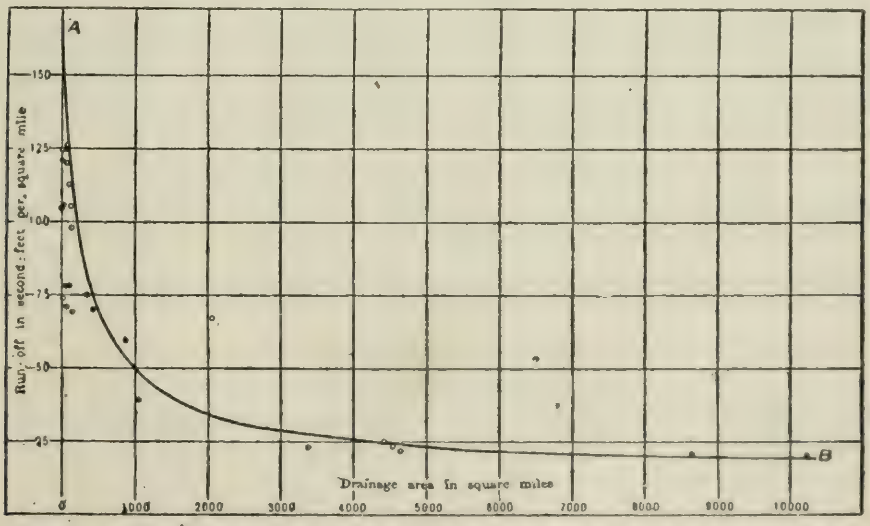



FIG. 19.—Curve showing relation between size of drainage basin and run-off per square mile.

The following table has been prepared from this equation and gives the maximum rate of flow per square mile from drainage basins of various sizes in the northeastern part of the United States. Knowing the size of the drainage basin at a given place on a stream in this section of the country, the maximum discharge is found by multiplying the drainage area in square miles by the proper value found in this table.

*Values of q, the maximum rate of flow of streams, in terms of M, the drainage area in square miles, in*

$$q=\frac{46,790}{M+320}+15$$

| Value of $M$. | Corresponding value of $q$. | Value of $M$. | Corresponding value of $q$. | Value of $M$. | Corresponding value of $q$. |
|---|---|---|---|---|---|
| 1 | 161 | 250 | 95 | 4,000 | 26 |
| 5 | 159 | 500 | 72 | 5,000 | 24 |
| 10 | 157 | 750 | 59 | 7,000 | 21.4 |
| 20 | 153 | 1,000 | 51 | 10,000 | 19.5 |
| 50 | 142 | 2,000 | 35 | | |
| 100 | 126 | 3,000 | 29 | | |

The mean velocity of flow in an open channel depends mainly on: (1) Slope of water surface; (2) shape of channel, its width, depth, and straightness; (3) roughness of bed and banks; (4) position of mouth of tributary streams; (5) obstructions in channel, such as ice gorges, dams of logs, drift, bowlders, etc.

The formula in general use for computing the discharge of a stream is—

$$Q=AV=AC\sqrt{RS} \qquad (1)$$

In this formula $Q$=discharge in cubic feet per second, $A$=area of waterway in square feet, $V$=mean velocity in feet per second, $S$= slope of surface, $R$=hydraulic radius=$\frac{A}{P}$ where $P$ is the wetted perimeter, and $C=\dfrac{a+\frac{b}{n}+\frac{c}{S}}{1+\left(a+\frac{c}{S}\right)\frac{n}{\sqrt{R}}}$ where $a$, $b$, and $c$ are constants and $n$ is the coefficient of roughness of bed. Solving equation 1, we have

$$A=\frac{Q}{V}=\frac{Q}{C\sqrt{RS}} \qquad (2)$$

If a simple method can be found for obtaining the value of $V$, then the waterway can be found by dividing $Q$ by $V$

The following table gives the values of $V$ for slopes varying from 0.1 foot per thousand to 20 feet per thousand, and for values of $R$ from 2 to 25 feet, for the case where $n=0.035$. It covers all cases of flood flow of ordinary streams.

*Table for finding the mean velocity in a chanenl from Kutter's formula when the cofficient of roughness n=0.035.*

| Slope in feet per thousand. | Hydraulic radius. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2. | 4. | 6. | 8. | 10. | 12. | 16. | 20. | 25. |
| 0.1 | 0.6 | 1.1 | 1.5 | 1.8 | 2.2 | 2.4 | 3.0 | 3.6 | 4.1 |
| .2 | .9 | 1.6 | 2.0 | 2.5 | 2.9 | 3.4 | 4.2 | 4.7 | 5.5 |
| .4 | 1.3 | 2.2 | 2.8 | 3.6 | 4.1 | 4.8 | 5.7 | 6.6 | 7.6 |
| .6 | 1.6 | 2.7 | 3.5 | 4.3 | 5.0 | 5.7 | 6.9 | 8.0 | 9.1 |
| .8 | 1.8 | 3.1 | 4.0 | 4.9 | 5.8 | 6.6 | 7.9 | 9.2 | 10.2 |
| 1.0 | 2.1 | 3.6 | 4.6 | 5.5 | 6.5 | 7.4 | 8.8 | 10.2 | 11.6 |
| 1.5 | 2.5 | 4.3 | 5.5 | 6.7 | 7.9 | 9.0 | 10.8 | 12.5 | 14.0 |
| 2.0 | 2.9 | 4.9 | 6.4 | 7.8 | 9.1 | 10.3 | 12.3 | 14.3 | 16.4 |
| 3.0 | 3.7 | 6.0 | 7.8 | 9.5 | 11.2 | 12.8 | 15.0 | 17.5 | 19.8 |
| 4.0 | 4.2 | 7.0 | 9.1 | 10.9 | 12.8 | 14.6 | 17.7 | 20.2 | |
| 6.0 | 5.0 | 8.5 | 10.7 | 13.7 | 15.4 | 17.7 | 21.5 | | |
| 8.0 | 5.8 | 9.6 | 12.6 | 15.6 | 17.8 | 20.4 | | | |
| 10.0 | 6.5 | 10.7 | 14.0 | 17.3 | 20.0 | | | | |
| 15.0 | 8.0 | 13.3 | 17.8 | 21.0 | | | | | |
| 20.0 | 9.3 | 15.3 | 20.0 | | | | | | |

It can be shown that the hydraulic radius

$$R=\frac{A}{P}=\left(\frac{(I+2d)\,X}{(I+2d)\sqrt{1+X^2}}\right)d \tag{3}$$

in which $I$ is the bottom width of a trapezoidal section, $d$ is the depth, and $X$ is the slope of the sides. It can be seen from equation (3) that for any given values of $d$ and $X$, $R$ approaches $d$ as $I$ increases; for the case of floods, therefore, it may be assumed that $R=$ the difference in stage between high and ordinary low water. Any error in the assumption that $R=$range of stage makes $R$ too large, the mean velocity too large, and the computed waterway too small. If desired $R$ can easily be obtained from a measurement of the chosen cross section.

Briefly stated, this method of finding the waterway at a given place on a stream consists in finding the drainage area in square miles above the place under consideration, the greatest change in stage of the stream at this place, and the slope of the surface. By multiplying the drainage area $M$ by $q$ (p. 188), we find $Q$; dividing $Q$ by $V$

(p. 190, using for $R$ the maximum range of stage, and for $S$ the measured slope of surface of stream, we have the necessary area of the waterway.

The greatest error in the use of this method will result from an incorrect measurement of the slope. The formula calls for slope of surface, and surface slope of a stream is not necessarily the slope of the bed. The slope is not the same at all stages nor always the same for a given stage. If the place under consideration is near the mouth of a large tributary the slope of the main stream will be affected by the stage of the tributary. Overflow and flooding of lowlands is frequently the result of backwater, due to reduction of surface slope. The smaller the slope used the greater will be the computed waterway.

If there is a possibility of the waterway becoming partly clogged with drift, logs, or ice, or its being in the influence of backwater from a tributary, the computed area must be increased by a liberal amount.

The following tables give the maximum rate of flow of streams in various sections of the United States, the date of occurrence, the area of drainage above the station, and the authority. Nearly all these data were obtained with current meter; a few, however, were computed from cross-section and surface-slope measurements.

## GENERAL SUMMARY.

Floods on northern streams may result almost entirely from the rapid melting of snow and ice, there being very little rain during the flood.

Floods on northern streams are sometimes produced by ice gorges. The stream may reach a high stage and large areas along the stream be overflowed, while the volume of discharge is comparatively small.

Many of the floods in the western part of the United States are of short duration, produced by heavy storms of short duration, popularly called "cloud-bursts."

The area submerged during a flood depends on slope of stream bed and size of channel. In the lower part of the drainage basin, where the slope is small, the area submerged is larger than in the upper part.

The channel of streams is frequently reduced in width through cities, and overflow results therefrom. The bridges across streams frequently obstruct the waterway to a considerable extent. Too many piers are used, and the pier protection prevents the natural deepening of the channel during floods. The abutments are frequently placed at the low-water line instead of near the high-water line. The control of streams subject to overflow should be in the hands of an engineer or a competent body of men who will prescribe

the proper width of channel and the design of structures over them, and have charge of the work of overflow prevention.

Channel cross-section area should be a function of slope of stream as well as of drainage area and section of country.

Problems of stream control, protection of land along streams, and reclamation of swamp land are rapidly coming to the front in this country, and data bearing on their solution are in demand. In California and Kansas more has recently been done along these lines than in any other State.

The United States Reclamation Service is solving the flood problem in the semiarid region by the construction of reservoirs for the storage of the flood waters for use in irrigation. Destructive floods will eventually be unknown on the streams in this region.



*J. W. Alvord*— M. W. S. E. —The railroad engineer confronted with the necessity of deciding upon the area of water way for culverts and small bridges as a comparatively side issue to his main stock of information is plunged into one of the most difficult problems that confront the Hydraulic or the Municipal Engineer, that of deciding not alone the maximum run-off from watersheds of varying physical characteristics, which is a most difficult problem in itself, but to arrange for the maximum capacity which wise economy and prudent responsibility can afford under all the circumstances. In many cases when extensive railroad washouts occur, the fault does not lie in original inadequate understanding of the problem, but from the results of the one heaviest storm of the half century, which it is hardly practicable to provide against. It would nevertheless seem from some of the instances related in Mr. Bremmer's paper that the subject is not any too well understood.

The problem is essentially the same as that of providing for flood flow over dams, the collection of water supplies from small watersheds, the diking of reclaimed land, the removal of the rainfall from cities and the determination of the maximum water power from streams It is a fundamental necessity in designing structures for all such purposes to know the run-off and the capacities of the channels to carry the flood waters.

The first thought is naturally that the amount of rainfall and the area of the watershed are the two controlling factors, which

once carefully determined, render the remainder of the problem one of mathematics only. **I have** elsewhere*endeavored to point out that this is a fallacy, and that there are not less than 16 important factors which must be carefully studied before any formula can be applied, and while the amount of precipitation and the area of watershed are fundamental factors, they are often tremendously modified by other important factors, among which are the following:

1st. Character of the soil. Sandy country, like parts of Michigan and Wisconsin do not usually have excessive floods and the same is equalized by soil retention, yet with frozen ground and melting snows, such watersheds may yield abnormal flow.

2d. Steepness of the slope, or roughness of the area. Usually rugged watersheds have quick, sharp rises, while in flat areas the flood flows pass off slowly.

3d. Intensity of rainfall—this usually operates to accentuate flood flows in smaller districts—larger districts being less liable to be completely covered with high intensity of rainfall at one time.

4th. Character of surface. Forested or improved; bare land or cultivated; well drained or vice versa.

5th. Retention of water supply in lakes or marshes which tends to equalize the flow.

6th. Shape of watershed. Long and narrow watersheds discharge more slowly than fan-shaped or rectangular areas.

7th. Formation of drainage vehicle, that is to say, preliminary saturation of the soil—a period of wet weather followed by heavy rainfall will deliver nearly all of the final rain where it would be largely absorbed if falling upon the same area after a drouth.

8th. Melting snows in a Northern climate with frozen ground are generally responsible for many abnormal floods.

9th. Direction and velocity of storms. A storm moving in the general direction of the outlet intensifies the run-off.

10th. Deforesting of the country which tends to increase the run-off through long series of years.

11th. Size of the drainage area, large areas being less liable to cumulative influences.

12th. Arrangement of tributaries. They may converge at one focal point or may distribute their auxiliary floods uniformly along the main stream.

13th. Steepness of stream bed which usually creates quick, high rises, passing off rapidly. Rapid fall to stream bed, however,

*Discussion on Excessive Precipitation at Chicago. Journal Western Society, April, 1899—Vol. IV., No. 2.

up to certain limits, allows large increases in run-off without considerable increase in gauge height.

14th. Artificial control, by means of dams, storage reservoirs, reductions of stream bed by bridge piers, dikes, and the like above the point at interest.

15th. The formation of ice gorges and their destruction.

16th. The encroachment of towns and cities upon the effective streams cross section. This is a common and fruitful cause which works insidiously to create unexpected flood height at points where they do the maximum of damage.

To determine the results of all these variables by the application alone of even the best known formulas is the height of folly. It is loading up a two-horse formula with a 16-horse load. To determine run-off by any approximate method, such as the obtaining the square feet of the proposed water opening derived as a mathematical function of the watershed is like determining the amount of powder in a keg by means of a candle, there is just a remote possibility nothing might happen which would be disastrous.

To illustrate, discharge through a given opening is so predominately a function of surface slope of the flood that a given flood might completely fill an opening and yet vary from 1 to 10 or 15 times in volume discharged by reason of increased velocity. When to this uncertainty is added the uncertainty of the variations in amount of run-off from equal areas as outlined above, it is a question whether the problem is not approximating the engineer rather than the engineer approximating the problem. Old Frontenus, who was Superintendent of the water works at Rome about 2,000 years ago, used this method in gauging his aqueducts and although he held his job a respectable length of time, he found it as hard work to reconcile the discrepancies as the engineer of today.

The problem really divides itself into two parts:

1st. The capacity of the opening.

2d. The quantity which will reach it.

The mean velocity of the flow through an open or closed channel in feet per second is a function.

1st. Of the surface slope of the stream, $=S=\frac{h}{l}$ (in feet.)

2d. Of the area of the cross section divided by the wetted surface, or the hydraulic mean depth, $=R=\frac{a}{p}$ (in feet.)

3d. By the roughness of the channel which has to be determined experimentally, $=C$.

This is expressed in the well known Chazy formula.

$$\text{Velocity}=C\sqrt{R\ S}$$

from which the *quantity* may be derived by multiplying the mean velocity by the area. The surface of the stream may be roughly derived from the general descent of the valley, ravine or draw, but care must be used in making such an approximation to see that obstructions even a considerable distance away do not modify the surface slopes of floods. Wherever possible floods should be guaged by current meter or floats, generally a difficult proceeding. Failing in this the actual water surface slope should be measured wherever there is an opportunity and as accurately as possible, and it will still be remembered that a rising flood increases the slope and a falling flood diminishes it. The factor R is a matter of ready measurement, but C may vary from 30 to 150. For ordinary culverts it may range from 60 to 120, in streams it may be 40 to 100.

The annexed diagram gives a graphical solution of Chazy's formula was prepared by Prof. D. W. Mead of this Society and the writer for the study of the hydraulics of Coal River in West Virginia, and is a convenient method of solution, especially where large numbers of determinations have to be made, or where it is desired to study the relations to each other of the different factors in the formula.

The large variations of the value of C. have always been one of the chief difficulties in the ordinary use of the formula. This factor is found:—

1st. To increase with the size of the stream, that is with R.

2d. To increase with the surface slope except in small shallow streams.

3d. To increase with the slope of pipes met with in practice.

4th. To increase the smoothness of the wetted surface.

The obvious difficulties of dealing with such a variable as this has caused extensive studies and observations to be made which are embodied in the formula of two Swiss Engineers, Messrs, Ganguillet and Kutter. This formula, which is entirely devoted to the determination of C in Chazy's formula under conditions of wide variations in the other factors, is more complicated than Chazy's formula itself, and it is best and most conveniently used in the form of a diagram like the one submitted herewith from which the value of C can be readly read off and substituted in Chazy's formula.

It is obviously impossible within the limits of a reasonable discussion to go into a full understanding of the scope and efficiency of these formula under all conditions. Sufficient to say that in all ordinary cases when intelligently applied by having a full knowledge of their limitations, results of substantial and practical ac-

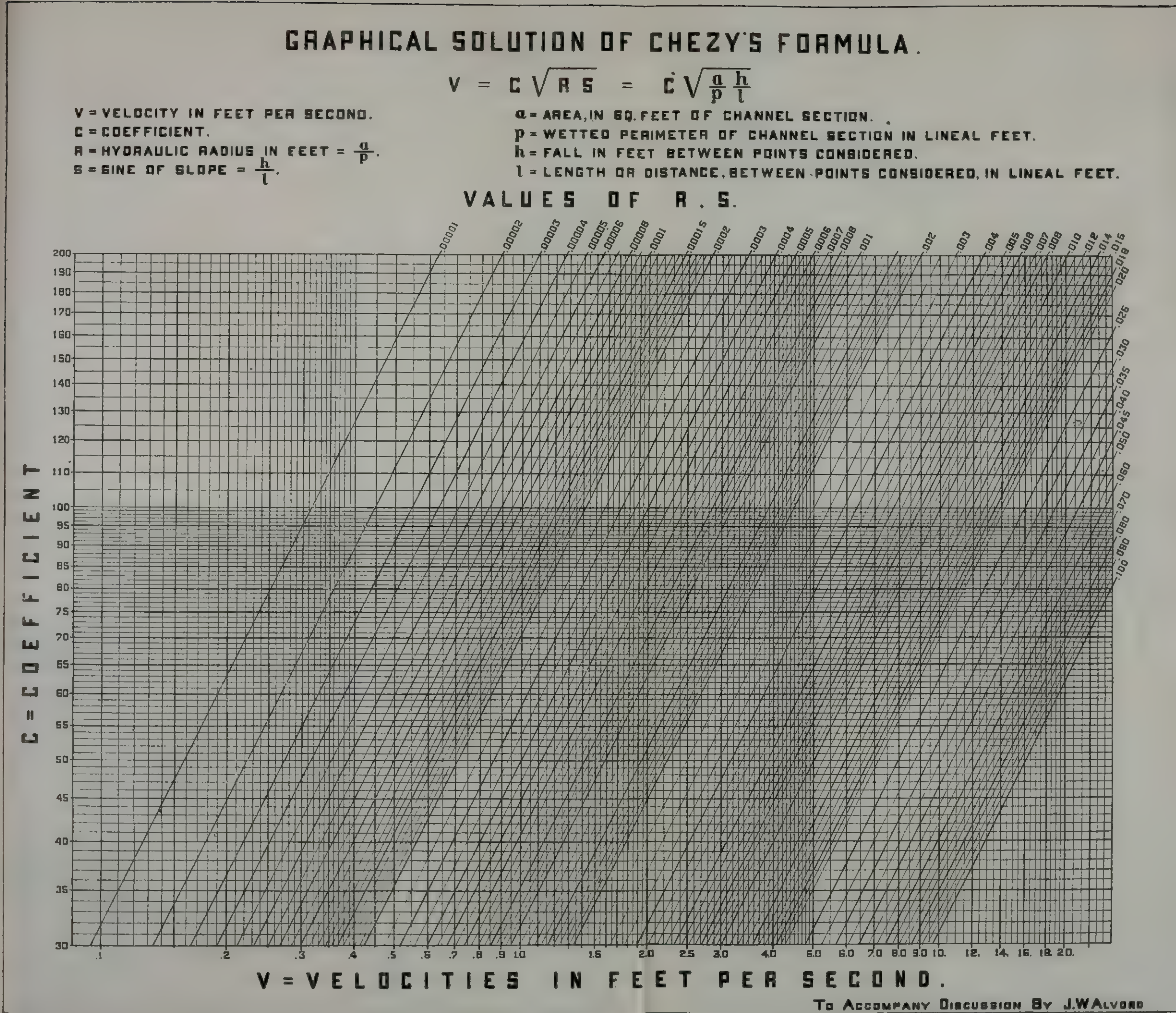

GRAPHICAL SOLUTION OF CHEZY'S FORMULA.
$V = C\sqrt{RS} = C\sqrt{\frac{a}{p}\frac{h}{l}}$
V = VELOCITY IN FEET PER SECOND.
C = COEFFICIENT.
R = HYDRAULIC RADIUS IN FEET = $\frac{a}{p}$.
S = SINE OF SLOPE = $\frac{h}{l}$.
a = AREA, IN SQ. FEET OF CHANNEL SECTION.
p = WETTED PERIMETER OF CHANNEL SECTION IN LINEAL FEET.
h = FALL IN FEET BETWEEN POINTS CONSIDERED.
l = LENGTH OR DISTANCE, BETWEEN POINTS CONSIDERED, IN LINEAL FEET.
VALUES OF R. S.
C = COEFFICIENT
V = VELOCITIES IN FEET PER SECOND.
To Accompany Discussion By J. W. Alvord

Fig. 9.

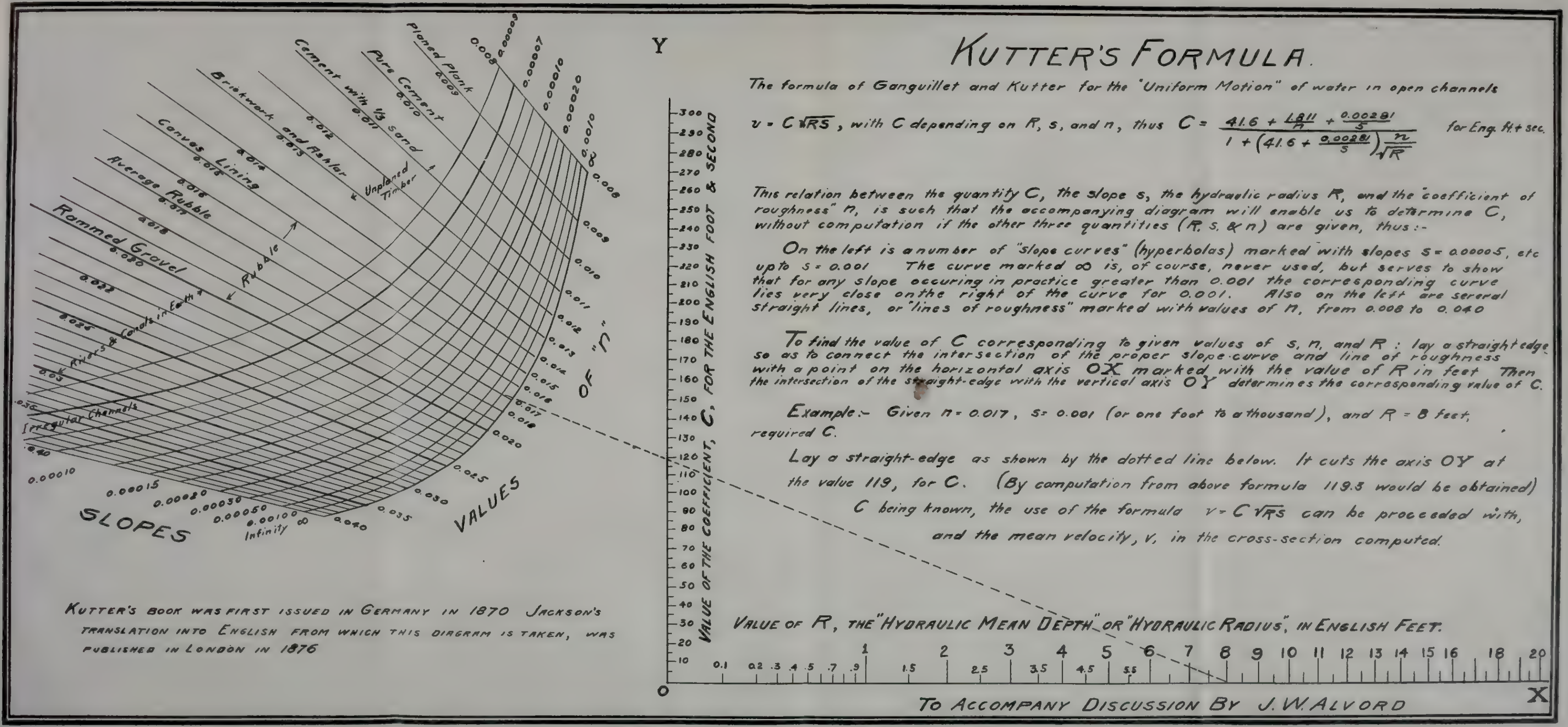

KUTTER'S FORMULA.
The formula of Ganguillet and Kutter for the "Uniform Motion" of water in open channels
v = C√RS, with C depending on R, s, and n, thus C = (41.6 + 1.811/n + 0.00281/s) / (1 + (41.6 + 0.00281/s) n/√R) for Eng. ft. + sec.
This relation between the quantity C, the slope s, the hydraulic radius R, and the "coefficient of roughness" n, is such that the accompanying diagram will enable us to determine C, without computation if the other three quantities (R, s, & n) are given, thus:-
On the left is a number of "slope curves" (hyperbolas) marked with slopes s = 0.00005, etc up to s = 0.001. The curve marked ∞ is, of course, never used, but serves to show that for any slope occuring in practice greater than 0.001 the corresponding curve lies very close on the right of the curve for 0.001. Also on the left are several straight lines, or "lines of roughness" marked with values of n, from 0.008 to 0.040
To find the value of C corresponding to given values of s, n, and R: lay a straight edge so as to connect the intersection of the proper slope curve and line of roughness with a point on the horizontal axis OX marked with the value of R in feet. Then the intersection of the straight-edge with the vertical axis OY determines the corresponding value of C.
Example:- Given n = 0.017, s = 0.001 (or one foot to a thousand), and R = 8 feet, required C.
Lay a straight-edge as shown by the dotted line below. It cuts the axis OY at the value 119, for C. (By computation from above formula 119.3 would be obtained)
C being known, the use of the formula v = C√RS can be proceeded with, and the mean velocity, v, in the cross-section computed.
Y
VALUE OF THE COEFFICIENT, C, FOR THE ENGLISH FOOT & SECOND
300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
O
X
VALUE OF R, THE "HYDRAULIC MEAN DEPTH" OR "HYDRAULIC RADIUS", IN ENGLISH FEET.
0.1 0.2 .3 .4 .5 .7 .9 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 9 10 11 12 13 14 15 16 18 20
Planed Plank 0.009
Pure Cement 0.010
Cement with 1/3 Sand 0.011
Brickwork and Ashlar 0.012 0.013
Unplaned Timber
Canvas Lining 0.014 0.015
Average Rubble 0.016 0.017 0.018
Rubble
Rammed Gravel 0.020 0.022
Rivers & Canals in Earth 0.025 0.03 0.035
Irregular Channels 0.040
0.00005 0.00007 0.00010 0.00020 0.0010 ∞
0.008 0.009 0.010 0.011 0.012 0.013 0.014 0.015 0.016 0.017 0.018 0.020 0.025 0.030 0.035 0.040
VALUES OF "n"
0.00010 0.00015 0.00020 0.00030 0.00050 0.00100 Infinity ∞
SLOPES
KUTTER'S BOOK WAS FIRST ISSUED IN GERMANY IN 1870. JACKSON'S TRANSLATION INTO ENGLISH FROM WHICH THIS DIAGRAM IS TAKEN, WAS PUBLISHED IN LONDON IN 1876
TO ACCOMPANY DISCUSSION BY J. W. ALVORD

Fig. 10.

curacy may be expected. For culverts or small bridges the "n" in Kutter's formula should usually be taken at not less than .035.

The second part of the problem, that of determining the run-off is a much more difficult matter than the determination of the capacity of the opening as has already been shown. No known formula even approximates all the conditions and the best formula are those which have a coefficient which may be widely varied to suit the judgment of the engineer, like the "C" in Chazy's and the "n" in Kutter. One of the best known formulas for the run-off is the Burkli-Ziegler form in which—

R equals rainfall in inches per hour.

A equals acres of watershed.

S equals mean slope of watershed in feet per 1,000 along the line of drainage.

C equals an experimental coefficient varied for different character of watershed.

Then as used in this vicinity for sewer run-off

$$Q = C\ R\ \sqrt[5]{A^4 S}$$

for ordinary use in the suburbs of cities "C" varies from 0.15 for outlying and thinly settled territory to 0.75 for completely paved built up and impervious districts, 0.20 to 0.45 would represent ordinary rural conditions such as would obtain in railroad practice, 0.15 being reserved for flat forested watersheds with permeable subsoil.

The best possible authority for run-off is of course carefully observed measurements of all stages up to extreme flood height and extending over a long series of years. This is knowledge absolute, all else is approximate.

Of recent years engineers are waking up to the value of recording such observations for the general use of the profession and the general government has very wisely devoted a large amount of time and money to their accumulation and study.

The next best possible authority for run-off is a carefully studied comparison of the watershed under consideration with a considerable number of other watersheds of a similar size, physical character and rainfall, whose run-offs have been carefully gauged over a series of years, and are known with reasonable accuracy.

Hydraulic engineers are always on the alert to add to the general store of knowledge upon this subject, because the more the common stock of knowledge increases by the increasing number of watersheds gauged and described, the more certainly can new watersheds be approximately estimated by comparison with those of known run-off under given rainfall and other conditions. The

tabulation and study of such watersheds is a specialty by itself and generally requires more time, expense and attention than can be given to it by the general practitioner or the specialist in other lines. A working knowledge of hydraulic formula, catchment formula, and drainage formula is necessary. A knowledge of how to study rainfall data, evaporation, seasonal variation in evaporation and plant absorption is also essential. A large acquaintance with varying watersheds, not alone by the accumulation of descriptive data but by the personal examination and study is desirable. The literature upon this subject is extensive and the accumulation of an up-to-date working hydraulic library is by no means an easy or simple task, involving as it does the accumulation of many pamphlets and special reports not generally accessible and often absolutely unavailable by the early exhaustion of limited editions. The wider the range of quickly available information, the broader the experience, the more careful the study, the more certainly can the run-off be predicted from area of watershed.

The cubic foot per second per square mile of watershed forms a convenient and useful unit with which to begin comparison of one watershed with another. This unit is of course lower on larger watersheds and progressively higher on the smaller areas.

Studies for the run-off of railroad culverts and bridges of the smaller openings are partly analagous to the problem of run-off in small streams, such as are usually studied for water power and water supply, and partly analagous to the run-off problem for farm drainage districts and larger combined sewer districts in the outskirts of cities. Large rivers bridged by the railways usually have their run-off carefully studied. It is the smaller openings that are approximated. With a view to this particular field the annexed diagram has been prepared giving the maximum run-off in cubic feet per second per square mile from small streams and from large sewer districts. From this diagram may be observed the rapidity with which the unit decreases with the increase in drainage area.

The upper curve upon the diagram is intended by its originator to include the exceptional storm. In sewer or drainage work it is not customary to provide for these excessive rainfalls as they are of rare occurrence and the extra cost of conduits necessary to convey would be excessive and unwarranted. About once in 40 or 50 years there occurs a combination of conditions which produce an excessive flood, and these floods are of such rare intervals that the interest on the extra investment necessary to provide for them would be many times the amount of damage occasioned by neglecting them.

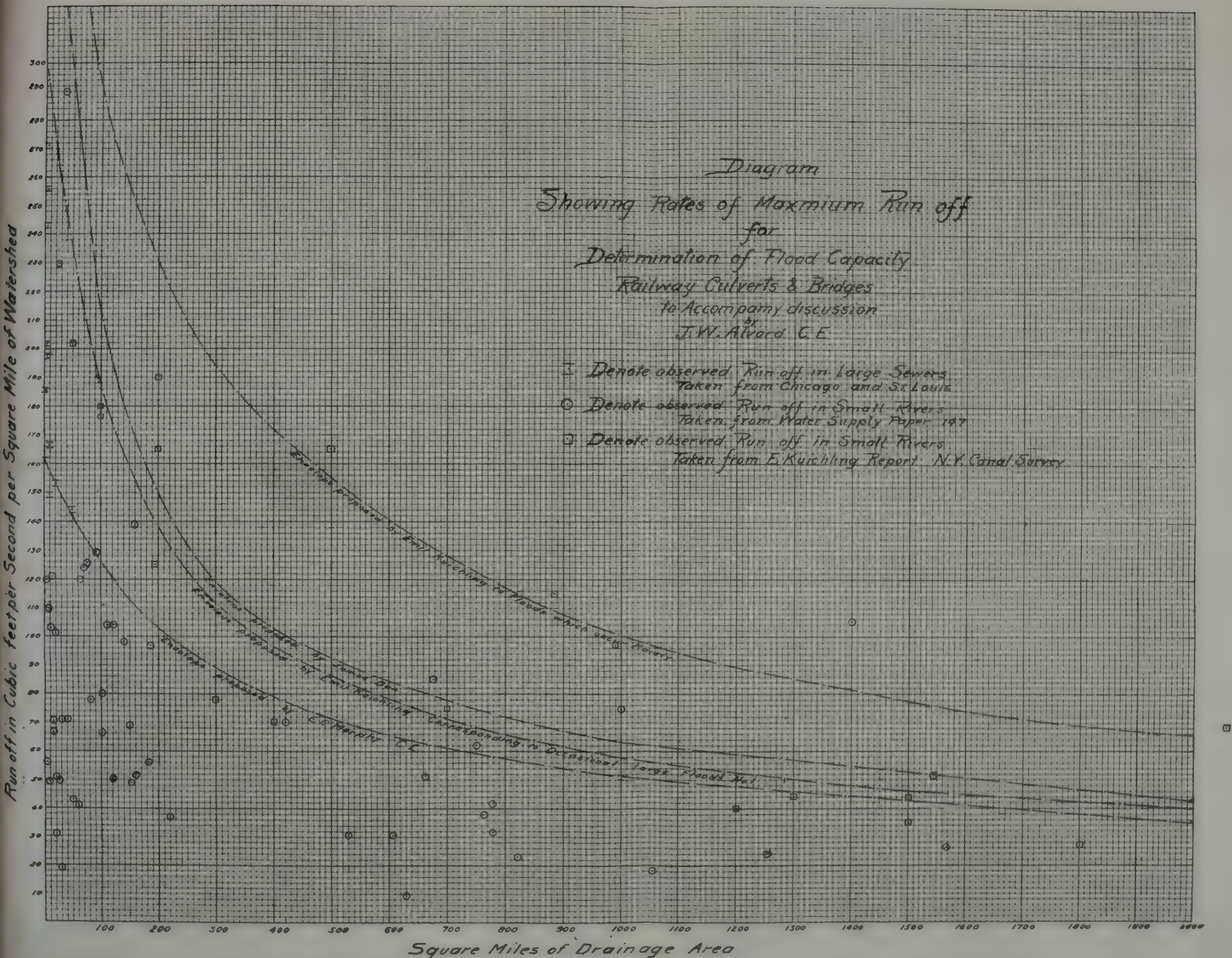
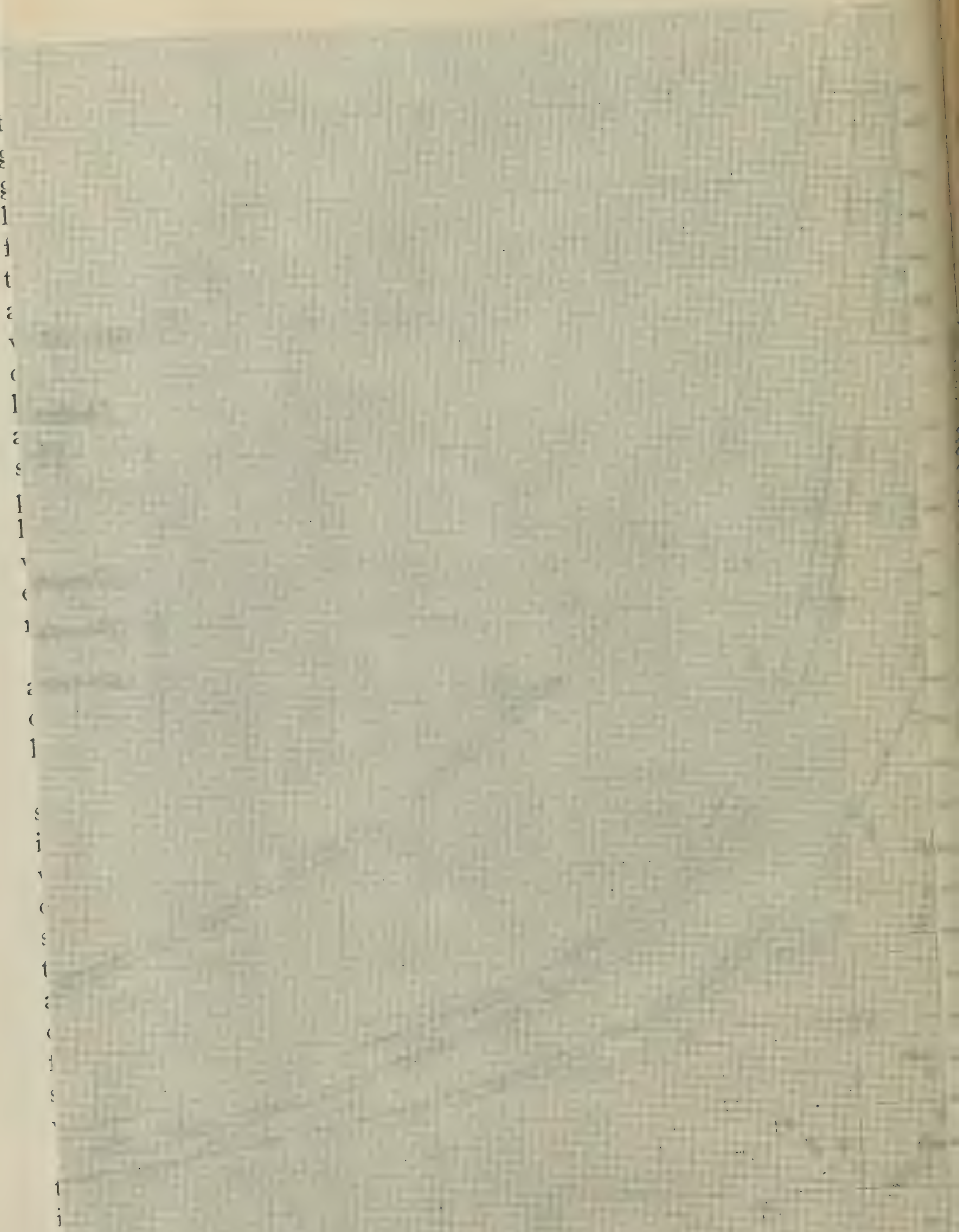


Diagram
Showing Rates of Maxmium Run off
for
Determination of Flood Capacity
Railway Culverts & Bridges
to Accompamy discussion
by
J.W. Alvord C.E.
Denote observed Run off in Large Sewers
Taken from Chicago and St Louis
Denote observed Run off in Small Rivers
Taken from Water Supply Paper 147
Denote observed Run off in Small Rivers
Taken from E. Kuichling Report N.Y. Canal Survey
Run off in Cubic feet per Second per Square Mile of Watershed
Square Miles of Drainage Area

Fig. 11.



It is therefore more common to provide for storms such as are below the number one curve proposed by Mr. Kuechling.

The curve proposed by Mr. E. C. Murphy is also one which is suggested as a compromise for excluding the very heaviest storms, but while it is apparently fairly high for areas over 200 to 300 square miles, it would seem to me to be too low for very small areas, below 15 or 20 square miles for instance, and the curve in use by Mr. James Dunn would seem to be better suited to the actual conditions in every part of its length.

Modifications could be made in all these curves for flat country with sandy soils. On the other hand, steep areas of bare soil subjected to cloud bursts, conditions often found in the arid Western part of the country, probably produce run-offs in excess of those here recorded.

I have not had time to carry this study further at this time. It would have been interesting to have carried out an additional diagram for smaller areas deduced from sewer practice and irrigation and agricultural drainage areas. In my opinion every railway company dealing with a large number of watersheds ought to have the results of generalized study in the form of such a diagram as I have here shown, with curves worked out for all the variations of soil, climate, precipitation, and physical characteristics that are found along its line and compiled from all the available data.

Finally, in railroad work where the lives and safety of passenger traffic is involved it would seem to me to warrant this sort of careful study on the part of the specialist to a much larger extent than is denoted by some incidents related in Mr. Bremmer's paper, and the use of less dangerous formula than the simple determination of culvert cross section area as a mathematical function of rainfall and drainage area.

The total investments of the railways in culverts and bridges in this country is very large. Much of the work done in an early day is being renewed. Fatal accidents due to insufficient appreciation of the difficulties of this question are all too common. The adoption of an empirical rule derived from a few extreme cases may produce a large number of wastefully large structures, while a lack of knowledge of the magnitude of floods may lead to costly and bitter experience. It seems to me that the whole subject is important enough for the close attention of a trained specialist.

This discussion must of necessity seem elementary to the Hydraulic Engineers, but it has seemed to me desirable to review the elements of the problem in order to impress the practitioner in railway works with the fact that the run-off problem has been well and attentively studied in connection with city sewerage, water

power, stream flow, and agricultural drainage, and is a problem of no mean order.

In closing it occurs to me to add that the railway engineer is in an excellent position to add to the sum total of the available knowledge upon the run-off question by putting on record the statistics of the watersheds crossed by his lines and their measured flood flows as well as other data. Most of this data stored away in railroad offices unpublished in any form, is useless to the general profession in its present condition. Were it accessible to tabulation generalization and study, it would form an invaluable addition to our knowledge of hydrology.

*Louis Kingman*—(of Mexican Central R. R., City of Mexico.)—This subject of drainage areas and the size of bridge openings has been quite carefully considered by city engineers in planning storm water sewer systems, but owing to the area receiving the rainfall and the great differences in the slope it has been exceedingly difficult to make a fixed rule to apply to the diverse conditions in the same locality; in other locations the rainfall varies so much that we are obliged to make excuses for almost any formula that has ever been devised.

Herewith are my instructions to Division Engineers:

"Sec. 3. The third important duty is to measure the drainage area of each waterway and secure notes, so as to determine how much to consolidate the several arroyos. All drainage areas that can be measured by the Division Engineer's force in two days should be measured. This work must be done carefully. Estimating or guessing at areas will not be tolerated. They must be measured, or triangulated, and the results carefully platted and worked out, and the notes sent in to the Chief Engineer at the earliest date practicable, so that the sizes of the bridges required to pass the water may be determined. The slopes of the area should be given, and the nature of the surface stated. The Division Engineer, after measuring the areas, is expected to give an opinion and recommendation as to what had best be done in each case.

Sec. 4. Th rule used will vary according to circumstances, but will be about as follows: The square root of the drainage area, in acres, multiplied by 3 for a flat, porous soil, where no water has been known to run on the surface; multiplied by 4 when it is flat and somewhat porous, multiplied by 5 on that portion of the country where the rains are heavy, and multiplied by 7 where the rainfall is very heavy and the slopes steep and bare. The square root of the area multiplied by these several numbers will give the sectional area in square feet for the bridge opening."

I have used these or other rules slightly modified for the last 8 years. We have put in many thousands of bridge openings; and have given careful attention to results; we have had some cases where the openings were not large enough but in most of these cases, the washout was due to cloud bursts that were sufficient to ruin any reasonable formula. The close proximity to a mountain range or of the slope of the plateau in the hot lands of the tropics has to be considered when determining the size of bridge openings.

Having a general rule and measuring the drainage areas and then using good judgment as to the annual rainfall and the qualities of the slope, has enabled the Engineer Department to reduce very largely the amount of bridging that was put in, 22 or more years ago, on this Railway. In some cases it was found that the openings were not large enough.

It is impossible to determine the annual rainfall, in many places in Mexico. In some localities it may not rain at all, in one year and the next year, rain so hard as to surprise the natives.

In all important streams, we measure the sectional area occupied by the stream, as shown by the high water marks.

With all the facts that we are able to obtain, the determination of the size of the bridge openings is a matter of judgment, but with the facts it is possible to guess pretty closely and there are not so many wild guesses as was made years ago.

I have had one bridge that has given us much trouble and expense.

In April, 1883, when appointed chief engineer of the northern or Chihuahua division of this road, I found the line located and graded across the San Pedre river near Ortiz. The grade was laid about 12 ft. above the bed of the dry river. I had a survey made five miles up the stream, ascertained the fall to be 5 ft. to the mile and the width 1,000 to 2,000 ft. but there was no good indications of the high water mark. I decided to raise the grade six feet and to put in seven 150 ft. spans, on masonry piers. While the was no water in this stream for six to ten months of the year, yet when there was water, it ran with great velocity.

The piers were sunk as deep in the gravel and stone of the river bed as we could go, even using two No. 8 centrifugal pumps, to pump out the underflow. In the foundation of the abutments, piles were driven with grillage and concrete below low water mark. The foundations were about 8 ft. below the surface of the underflow and usually 10 or 12 feet below the bed of the stream. About five years ago, one span was taken down and used elsewhere, thus reducing the bridge to six spans of 150 ft. in the clear or to 900 ft. width of bridge opening. On the seventh of September, 1904, there were very heavy rains in the mountains, which extended all over the San Pedre drainage area and the water came down with enormous quantities of drift wood. The water rose until it came up and over the rails; the water and drift picked up a span at a time, the first going at 1 P. M. and the last at 7 P. M., and deposited the spans 50 to 200 ft. below where they had stood, and undermined most of the piers.

We are now building dykes and raising the grade 9 ft. so that the new bridge will be 7 ft. higher than before and we will put

the piers down to 60 ft. below the new grade line. There will be 7 spans of 266 ft. each or 1862 ft. of bridging. This is more than twice the amount of bridging that was washed out. The old bridge has stood 21 years and there has been no high water to touch the bridge before. It was an innocent looking place with wheat and corn fields only a few feet above the arroyo bed, on both sides of the dry stream. With instances happening like this we must confess that theories and careful formula are at a discount.

## DISCUSSION.

*Mr. L. B. Merriam*— M. W. S. E.—(*by letter*)—In connection with Mr. Bremner's paper, I have found the Talbot formula, $W = C \sqrt[4]{A^3}$ to be a very handy formula. This follows very closely to Mr. Dun's curve. It is very true a large number of variables enter into the actual problem of computing the proper opening to allow under a railroad track for the passage of water, and the very careful determinations made by hydraulic and sewerage experts are very valuable in connection with this problem. They furnish the basis and the data for the formulation of formulae, but the final formula for use in the field must be reduced to the fewest and simplest possible terms. They must be terms that the ordinary assistant engineer can determine absolutely. On the preliminary and location surveys for a railroad the determinations for waterways need not be made with the extreme nicety, that is necessary later on, for as a rule temporary structures are used of timber, and those should be amply large. They should, however, be designed with a clear idea of what they are to do. The drainage area forms the simplest method of determining approximately the size of the opening required. These should be ascertained when the location surveys for a new railroad are made. It devolves, however, upon the permanent-way engineer to finally determine the sizes of the permanent structures to be placed in the railroad. If he is fortunate enough to be connected with the railroad from the start, he will have by the time the temporary structures need replacing, sufficient data in the different districts to be able to assign reasonably close values to the C of the Talbot formula or to the constants in any of the other accepted formulae, but he must have, as I have said above, a working formula with but very few variables. If permanent way engineers would instruct their assistants that whenever a severe storm occurs to measure the flow through the various culverts in the vicinity of where they may happen to be working at the time of the storm, these constants will become more and more accurate as the time wears on. We must, of course, take into consideration in the formation of these constants the general shape and slope of the valley and its condition as to tillage, but as a rule the shape and slope are by far the more important factors, because if your severe storm comes after a lighter storm of two or three hours'

duration, the run off will practically be the same whether the ground is under a high state of cultivation or whether it is simply pasture land. The run off to be considered and to be taken care of by the culverts is in every case the maximum ordinary storm; that is to say, the maximum storm which would occur at intervals of not exceeding three to five years; but where the extreme maximum is only slightly greater than the ordinary maximum, it should by all means be taken care of, and right here comes a point that is well worthy of consideration. If you have a busy railroad, a few hours' delay of the traffic would pay for a good sized culvert. I am inclined to favor the simplest class of empirical formula with the fewest possible terms. The basis of the final determination is after all largely a question of cultivated judgment. It is all right for the assistant engineer to determine all of the physical facts, but the man who is in responsible charge of the work should in every case see the situation, if he has not already a perfectly accurate knowledge of it.

I think the method of annual inspection of the bridges and culverts by the head of the engineer department on the division and head of the department of bridges and buildings personally at least once a year and systematically at a certain period of the year, is a very essential thing in the maintenance of the bridges and culverts of a railroad. It is the knowledge that is gained on these inspections which becomes more and more valuable in the determination of the final permanent structures to be placed under the track. From my experience I favor Mr. Dun's table very much more than that of Mr. Murphy for the reason that in the smaller areas a very much larger run off per acre should be provided for than in the larger areas. I am using Talbot's formula* with C=1-3 in Western Nebraska and C=1-6 in the central portion of Wyoming.

*Mr. T. C. Gray*— M. W. S. E. (*by letter*)—The formula which I have used with marked success for determination of size of openings for waterways is

$C\sqrt[4]{\text{Acres of water shed}^3}$; C being a variable coefficient as follows:

For steep and rocky ground =2-3

For rolling ground =1-3 when the length of valley is 3 times the width.

For rolling ground =1-5 when the length of valley is 5 times the width.

On all work under my jurisdiction, actual surveys are made of water sheds, and are platted on cross-section sheets (scale to suit); the formulæ are worked out on the same sheet and the recommendation given thereon; so that the whole situation is presented concisely before the management.

*See Prof. Talbot's discussion of this subject

*Mr. Lyman E. Cooley*— M. W. S. E. —It seems to me, in view of the importance of the subject, I can hardly treat it in an offhand way. The matter I would like to put before you ranges over about 25 years of hydraulic study on the Mississippi and Missouri rivers, with some experience also in Colorado, New York, Michigan, and on the Ohio river and some of its tributaries; also in Nicaragua. My study in these matters has come from the standpoint of the hydraulic engineer, dealing with the question of flood control, and especially in regard to waterway improvements, embankments, levees and water power. One of the first things to ascertain, when improvements for water power are to be made, is the maximum flood flow. The structures must be designed to meet that condition. The matter has to be approached more closely than is required in railroad practice. I will say, however, that as early as 1884 I had occasion to make a collection of formulæ upon this subject. Several formulæ have originated in the practice of Indian engineering, and I think from the reading of these papers, that most of these formulæ follow Dickens, using $\sqrt[4]{A^3}$ which is an Indian formula.

I made several measurements upon streams, varying from 10 square miles to 2500, in the state of Missouri, and deduced a formula from that, and found the variation at $Q=\sqrt[3]{A^2}$ I have applied that in my practice and find it works very well.

The question of the slope of the water-shed is of course important. At the same time there are several factors, about which judgment must be used, as the question of flood plains on a stream, and the amount of overflow; the way in which the tributaries are arranged that come into the valley of the main stream, and the shape of the basin itself. In other words, how the gathering ground brings the water together.

The question of storm tract is also a very important matter. For instance, take the Desplaines river, where we have the greatest flood of the century duly recorded (this river running north and south), and the Calumet river, running east and west; you will find the Calumet river has a much flatter basin generally, and that the flood flow is about 15 per cent greater than in the Desplaines river. On the north branch of the Chicago river it is only about two-thirds as great as in the Desplaines river.

In Michigan, in the timber and sandy regions, I have applied a basin ratio to extreme flood, and, with one or two exceptions, all the streams in Michigan flowed to the rule referred to,— $\sqrt[3]{A^2}$ In the Ohio basin, the constant is two or three times as great.

In the streams I have investigated, with records running over 100 years, there are about two or three floods in a century greater than the oldest inhabitants remember anything about. About once in a generation a flood comes along about two-thirds of the extreme, and in an average of one-half the years there will be a flood from

one-third to one-half of the extreme. The other half will be floods less than that, and seldom noted. That is about the rule in this country from the Missouri river to the Atlantic.

The greatest floods in this latitude are not due to rainfall conditions or character of basins, but to frozen ground. I have had occasion to investigate several streams in this latitude, and found that in 1894 the greatest flood ever known occured in the Grand river, Mich., but it was a flood that ran off on frozen ground. When you come to frozen ground the soil of the basin cuts little figure, and such a flood is usually followed by extreme low water in the following spring or summer.

Out in the arid regions of the west there are as many different climates as valleys, and in some parts the constant will be three or four times that in others.

I had occasion to make a careful investigation of the south fork of the South Platte river, draining the South Park, Colorado, and compared that with the Poudre and other streams, and I found that variation. We went into it very carefully, as the subject was in Court. We found a great many examples of cloud bursts, etc. But when we come to a basin as large as 1000 square miles, the cloud question is to be eliminated. Those down-pours do not break over very large areas. I have concluded it is possible in Colorado and throughout the arid regions, for a flood sometimes to occur as great as in Illinois, and in designing the spillway for the Cheesman dam we provided for as large a flood as might occur in this part of the country. I think we have data for such judgment. Take the history of the Yellow river in China, which drains part of the desert of Gobi, coming from the same arid region. Four floods are recorded in history which have drowned out populations of several millions of people, and the mouth of the river has been changed by 150 miles or more from the main sea to the Yellow Sea. So, at least once in 400 years a flood may occur exceeding all possible anticipation.

The subject is profoundly interesting, but there has been sufficient investigation to enable a sound judgment, in the application to railroad work, dam practice, and embankment work.

In the regulation of flow, we must consider the flood plains, climatic conditions, character of water-shed, and many other things.

*Mr. E. S. Rice*— M. W. S. E. —I would like to give some results of my observations from looking back over our records for the past 25 years.

Where we have indicated high water in Kansas, Colorado, and Oklahoma, I find that the high water mark every two or three years rises a foot or two, and that in drainage area, for instance, we would have to increase the water-way, on certain high water marks about every five years. Up to last year it almost doubled itself. I noticed some records we have were on small openings about 20 years old. All of our drainage areas at the present time are actually measured by the instrument party in the field, and on two or three

hundred cases of high water or floods that we have had in the last year or two (principally in eastern Kansas, Missouri, or Oklahoma) we find that Mr Dun's table fills the bill where there is a swift flowing stream.

The waterways given seem to be plenty, without an excessive amount of waterway, but in eastern Kansas, for instance, where we had an excessive flood, it was the slow moving water, or water that hardly moves at all, that does damage to a small opening. A great many of the drainage areas, of which we have old records, apparently were not taken as correctly as they are now.

*President Arnold*: Referring to what Mr. Rice has said about the high water mark rising a foot or two every two or three years, this is probably due principally, if not mainly, to the filling up of the beds of the streams with silt. While I hardly think this would raise the streams a foot a year, it undoubtedly does affect them by gradually filling the bed of the streams.

*Mr. J. N. Darling*— M. W. S. E. —I have before me a comparison of Mr. Bremner's table with that used on the A. T. & S. F. Ry., giving a few instances which I have taken at random, showing differences in sizes of openings, as between the two, for the same area drained:

| BREMNER'S TABLE | A. T. & S. F. Ry. |
|---|---|
| 30 acres, 5 sq. ft. | 30 acres, 8.55 sq. ft. |
| 300 acres, 24.3 sq. ft. | 300 acres, 63.6 sq. ft. |
| 500 acres, 33.2 sq. ft. | 500 acres, 87 sq. ft. |
| 950 acres, 45 sq. ft. | 950 acres, 148 sq. ft. |
| 1200 acres, 49.7 sq. ft. | 1200 acres, 187.5 sq. ft. |

Then comparing these with equal acreages in Talbot's formula, I find for Bremner a series of constants, as follows:

TALBOT.

| | | |
|---|---|---|
| 30 acres, | 5 sq. ft. | with constant .39 |
| 300 acres, | 24.3 sq. ft. | with constant .33 |
| 500 acres, | 33.2 sq. ft. | with constant .31 |
| 950 acres, | 45 sq. ft. | with constant .263 |
| 1200 acres, | 49.7 sq. ft. | with constant .244 |

But for the A. T. & S. F. Ry. practice, the constant C is greater, as here shown:

| | | |
|---|---|---|
| 30 A. | 8.55 sq. ft. | with C=.667 |
| 300 A. | 63.6 sq. ft. | with C=.882 |
| 500 A. | 87.0 sq. ft. | with C=.83 |
| 950 A. | 148 sq. ft. | with C=.87 |
| 1200 A. | 187.5 sq. ft. | with C=.92 |

An inspection of Bremner's formula and that used on the A. T. & S. F. R. R. in connection with Talbot's formula, shows that agreements in size of openings as between the latter and the two former

can be secured only by varying the constant C, of Talbot. Thus, for 30 acres Talbot agrees with Bremner by use of constant, 0.39, and for the same acreage he agrees with A. T. & S. F. by use of constant, 0.667. And through the several other cases, for agreement with Bremner the Talbot constant runs down to 0.244, while for an agreement with the A. T. & S. F. formula the constant runs up from 0.667 to 0.92.

This simply shows the great variation, under similar conditions, as between the three formulæ. The Talbot formula I understand was used as far south as Chickamauga Park and Chattanooga. In the A. T. & S. F. formula the great size of openings called for, is probably explained by the fact that it is used largely in the southwestern part of the country, where rainfall is more erratic.

This comparison of formulæ seems to show that in the correct use of the constant, is found the key to the situation, thus throwing the question back on the judgment of the engineer for a proper use of theoretical formulæ.

Mr. Cooley has mentioned the difference in the amount of flood in two different portions of a given river basin,—that is, a less amount of flood in the lower part of the valley than in the upper part. A case came under my observation in connection with the construction of a road in the Yazoo bottoms in Mississippi. On this line we crossed the same river twice. At the lower crossing I had a chance to see a phenomenally high water, and I saw that all the water went through between the so-called high banks. I got the extreme high water mark, and from it figured up the square feet of cross-section, required to carry the flood water, at about 7,000 sq. ft. Going 35 miles further north to the upper crossing, I noted the same conditions; in the same high water, there I found that it took 10,000 sq. ft. of cross-section to carry the flood water. In another high water, occurring the next year, I found that, at the upper crossing, which was near where the water came out of the hills, the opening was working over-time to carry off the flood water as it came, while the lower opening was not over-crowded.

*Mr. C. B. Burdick*— M. W. S. E. —I do not know that I can add very much to the valuable information presented tonight. I think it is of value to have set down the experience of large railroads in these matters. There is one thing that impresses me in connection with the paper and the discussion, and that is this: I am a little surpised that there is so little variation in the practice of the various roads in different localities. This is not in accord with the experience of designing storm-water sewers, with which I am more familiar. Some of those present will perhaps remember, that some five or six years ago there was here presented a very interesting paper on flow in storm-water sewers, and the author, Mr. C. D. Hill, presented a set of formulæ or curves which outlined the practice found to be sufficient for the city of Chicago.* Some ten or fifteen years ago a paper was presented before the American Society of

*Journal Western Society of Engineers, Vol. VII, p. 425, 1902.

Civil Engineers, by Mr. McMath of St. Louis, who presented some formulæ and some curves representing the experience which had been found satisfactory in St. Louis. This very significant fact will be evident from the examination of the conclusions presented by these two papers. It has been found that in St. Louis it is necessary to provide for about six times the capacity of water that has been found to be necessary in Chicago. No doubt the practice in both cities is conservative and proper, and there is no doubt but that the different conditions of topography are sufficient to account for the difference in the practice. These cases may be cited as instances illustrating the great variation in the quantity of water to be provided for in sewers.

An examination of the table presented showing the provision for area of waterway on the "Santa Fe Railroad," shows an extreme variation of not more than 100 per cent in the allowances in different localities, although the road covers all the States from Illinois southwest: that is, the greatest allowance exceeds the smallest by only 100 per cent. As is explained in the paper, the table is, however, to be used only as a guide, and the extremes in its application possibly show a larger variation. Even so the variation in provision for flows in the different localities seems very small, as compared with allowances made in water power work and also in city sewerage.

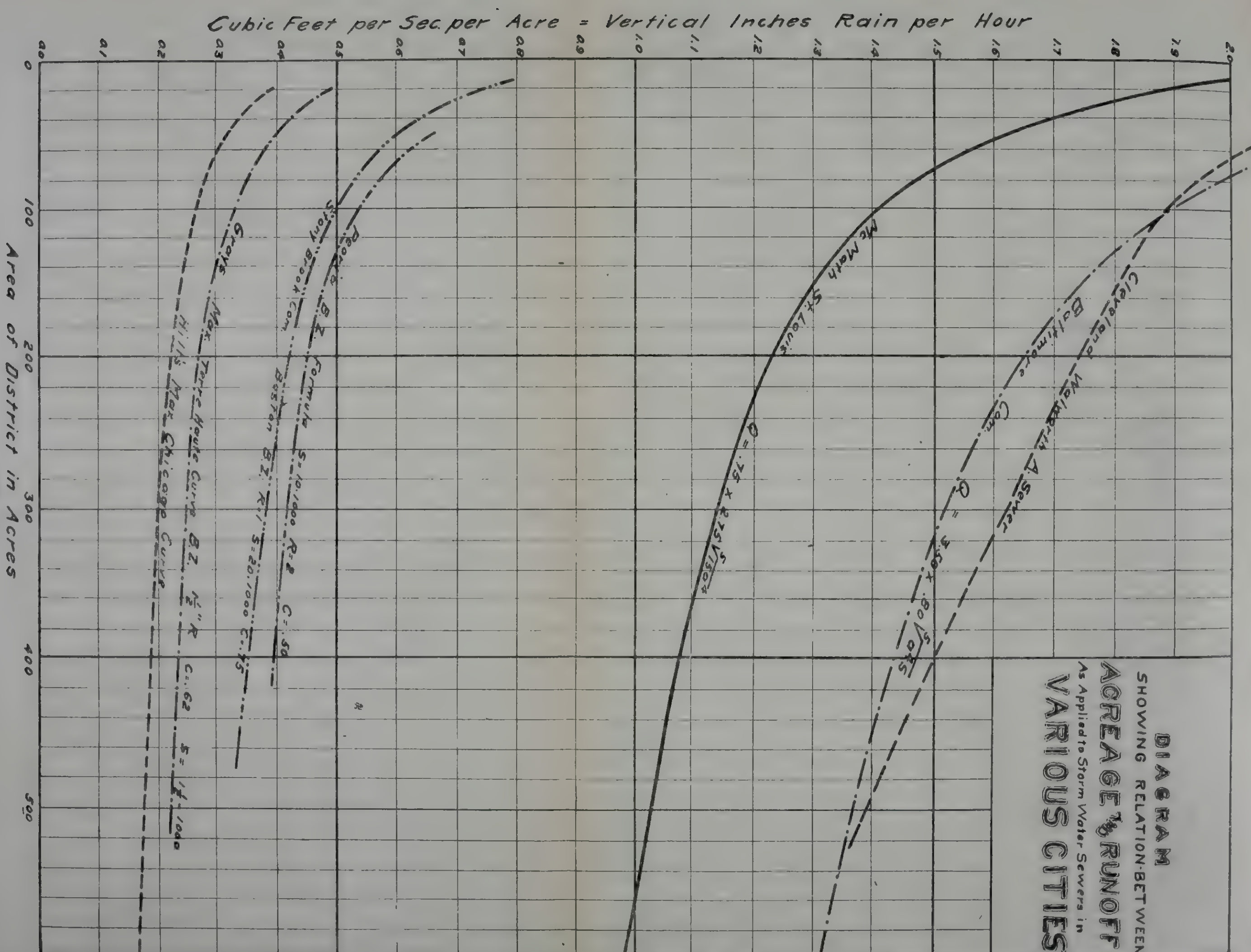
The diagram herewith presented (Fig. 12) illustrates the widely varying allowances made in designing storm water sewers in various cities, differing widely in topography and other conditions affecting the run-off.

*President Arnold*—What is the reason for that variation?

*Mr. Burdick*—It is very largely due to the difference in the surface topography. We have flat slopes in Chicago. In St. Louis the ground is more rolling. I do not think that in St. Louis the floods are particularly large as compared to Chicago. At other places between here and St. Louis it is necessary to provide flows between the Chicago curve and the St. Louis curve, and I would say, in that connection, that these matters can be most easily seen by graphical diagrams. The advantage of a diagram over a formula, it seems to me, is similar to the advantage of map over a description of a country.

*President Arnold*—I am quite familiar with the city of St. Louis, and have had a little experience with drainage of areas, and my experience is that where the pitch is great, sizes can be smaller. That is, if the flow of the water is sluggish you would have to have a greater area. I do not know much about sewers here, and would ask if you have to keep a certain volume of water flowing at one time?

*Mr. Burdick*—The problem of the storm water is divided into two parts,—the quantity of water that reaches the sewer and the size of sewer that is required to take the water off. The first is rather a complex problem, but the second is more simple. In a town of



Cubic Feet per Sec. per Acre = Vertical Inches Rain per Hour
Area of District in Acres
DIAGRAM
SHOWING RELATION BETWEEN
ACREAGE & RUNOFF
As Applied to Storm Water Sewers in
VARIOUS CITIES
Mc Math St. Louis
Cleveland Walworth A. Sewer
Baltimore Com.
Grays Max. Terre Haute Curve B.Z. 1½" R
Hills Met. Chicago Curve
Story Brook Com. Boston B.Z. R. 1 S = 20/1000 C. .75
Peoria B.Z. Formula S = 10/1000 R. 2 C. .50


Fig. 12.

steep grades the water comes to a sewer faster than in a town where the grade is more even. In a town of steep grades the water will run away from a sewer of given diameter much faster than in a town of flat grades, but you will see that the problem is divided into two parts.

*Mr. Cooley*—The streams upon which I based my formula were measured in the vicinity of St. Louis. That was my headquarters for six years. It may be interesting to note the fact that the Desplaines river, in its natural extreme flood flow, has parctically the same constant as the streams 20 or 30 miles north of St Louis, so the variation in natural streams is probably much less than in sewer systems of cities throughout the same territory. I presume that is explained by the smaller area drained by sewers, and the fact that intensity of rainfall and the question of declivity in a paved city cuts a much larger figure than it does in natural streams.

When on the Intercepting Sewer Commission in Chicago, I undertook to test the sewer systems of Chicago by these stream formulæ, and, if I remember correctly, the standard practice in Chicago does not provide for as much flood as runs out of the Desplaines river. The standard practice of St. Louis provides for two or three times as much. I refer the student of this subject to Craig's formula,* published in the proceedings of the Institute of Civil Engineers some 20 years ago, which attempts to discuss the whole subject with all its factors, based on a lot of experimental measurements in Australia, but I have not seen anything since, where so broad and analytical a presentation of the matter in the way of a formula, has been attempted.

It has occurred to me to mention some facts in regard to the floods of the Ohio river. The great flood of the Ohio river was that of 1832. The oldest inhabitants recalled nothing that began to equal the flood of 1832, and there were records going back into the preceding century,—perhaps 50 to 80 years prior to 1832. There was no flood on the Ohio river exceeding the one of 1832 until 1884. In the flood of 1884 Lawrenceburg, Indiana, was wiped out and two or three other towns That flood was four feet above the one of 1832, and it is significant that it occurred after a man had done his work on the water-shed. The people said, it has been 50 years since the flood of 1832, and we will not have another for 50 years. Then there came another flood in 1886 which went two feet higher. This question of the succession of floods is something we cannot tell about, and the only safe way is to provide for anything which can occur. It is a law of probability that whatever is possible will sometime happen.

*Mr. O. P. Chamberlain*—The methods employed on the C. B. & Q. Ry. for determining the areas of waterways for culverts and bridges as set forth in detail in Mr. Bremner's paper may be regarded as typical in railway practice in the United States.

In determining the areas of waterways for small drainage areas the prevailing railway practice is, where local conditions permit,

to calculate the discharge of the flood water accumulating in the drainage basin at an assumed velocity rather than at the actual maximum flood velocity of the stream. A velocity of discharge of ten ft. per second is commonly used. As this velocity is much higher than the actual velocity of the natural water courses in flat and rolling countries, it is clear that culverts and arches so designed are smaller and more economical than they would be were they designed in accordance with the suggestions of Messrs. Murphy and Alvord in the paper.

Only in streams through rapidly sloping ravines and with large rivers, it is necessary to consider the actual maximum velocity of flood. In over eighty per cent of the bridge renewals, that are considered in the practice of a division engineer in this section of the country, he is in no wise interested in flood slopes or actual maximum velocities in the unobstructed channels. It might be well to add that at the very times when such information should be collected for any streams the division engineer is apt to be otherwise employed in repairing washouts and keeping his division open for passage of trains.

The use of the Chazy formula, as a check after a certain size of opening has been selected tentatively, is of advantage in designing important bridges for large streams where the engineering department has secured the information necessary to determine the flood slope.

It must, then, however, be a case of "try and fit" as the second member of the equation, Velocity $= C\sqrt{R\ S}$ involves in R, the hydraulic mean depth, and the value of A, the area of the cross section which we wish to determine. We can, however, with a selected value of A, solve for velocity and multiply its numerical value by the area to obtain the quantity discharged in cubic feet per second. If this is equal to, or less than the estimated maximum run-off, our opening is large enough.

Mr. Alvord in his discussion says:

"The problem really divides itself into two parts:

1st—The capacity of the opening.

2nd—The quantity which will reach it.

If we reverse these two statements we will have the order in which they are ordinarily and logically considered. We determine:

1st—The quantity which will reach the opening, Q, in cu. ft. per sec.

2nd—The area of cross-section of the opening, A, in sq. ft.

We will agree that the value of Q must be obtained by actual observation of the basin in question or by analogy. Now the fundamental difference between the methods of Messrs. Bremner, Dun and Kingman on the one hand and Messrs. Murphy and Alvord on the other is in the solution of the simple formula $A=Q\div V$

Mr. Murphy in his article substitutes the value of V in Chazy's formula $V = C\sqrt{RS}$ and gives us the equation $A = Q \div C\sqrt{RS}$ to solve for A. Here appears even more frankly than in Mr. Alvord's discussion, the difficulty before mentioned of determining A with a quantity R, itself involving A in the second member of the equation.

Now let us take the railroad engineer's view of the question. He says: "A flood will accumulate on the up stream side of my railroad embankment in a certain drainage area at the rate of Q ft. per sec. I know that I can discharge it through a cast iron pipe or through a box or arch culvert or between abutments with perfect safety to both the structure and embankment at a velocity of ten feet per second. My embankment is high enough to impound the water until there is sufficient head to produce this velocity, so I am safe in assuming this velocity." He substitutes 10 for V in the formula $A = Q \div V$.

Mr. Murphy says in his article.

"If a simple method can be found for obtaining the value of V then the waterway can be found by dividing Q by V." Perhaps this is the simple method he was seeking.

The point I wish to emphasize is that ordinarily, particularly in embankments where we use cast iron pipes or box or arch culverts, we are interested neither in the mean velocity of the flood nor the slope of the flood. Provided we have an embankment high enough to raise the flood on the up stream side to a head sufficient to discharge through the culvert at the assumed velocity of 10 ft. per sec. we have a safe culvert and a more economical one than had we designed it for the mean velocity through an unobstructed drainage basin.

All other things being equal, our values of Q for different bridges depend upon the respective areas of the drainage basins. Mr. Bremner has pointed out the necessity of care and experience on the part of the engineer in determining the proper treatment for bridge openings. Mr. Alvord has emphasized the fact that the character of the watersheds is important. In the investigation of causes of washouts I have frequently found that there has been carelessness in the investigation of the drainage area, or bad judgment in the selection or construction of the waterway.

I recall one case where a drainage area of twenty-two square miles had been reported as eight and an arch culvert put in accordingly. The culvert washed out the first season. In several cases box culverts had been built with the tops of openings at about the same level as the beds of the water courses they discharged.

The empirical formulæ used on the various railroads are the results of considerable investigation and are subject to modification as the records now kept on all railroads show where they are faulty.

With the first renewals of pile bridges with permanent structures on the western lines there was a perfectly reasonable demand from

railway managers that the amount of bridging be reduced. In many cases in replacing pile trestles with permanent structures the openings left were too small and too few and the results were disastrous. The situation is now receiving more rational treatment.

Where records have been kept on pile bridges, of flood water, these records combined with the judgment of a competent engineer, or bridge supervisor, are a safer guide for the design of permanent structures than any formula. Many times I have protested against the proposed shortening of bridges on which I had seen flood waters washing the stringers. But, I was told, the drainage areas did not call for so large openings.

In a flat country the line of demarkation between drainage areas is very difficult to determine. Here in Cook county, for example, it is impossible, in places, to definitely locate the watershed between the Desplaines Valley and the South Branch of the Chicago River. In heavy floods, shallow basins overflow into deeper ones, sometimes washing out bridges and culverts.

A careful record of the heights of floods at the bridges, is invaluable to a railroad. Where no better information is obtainable, we must depend on our empirical rules. All of these, as Mr. Bremner says, of his own formula, leave room for much future improvement.

For the purpose of comparison I platted roughly on Fig. 5 in lead pencil the curve of Mr. Dun's table, using 80% of the areas of cross sections given in the second column. I also platted the curve of the formula used by Mr. Kingman with the co-efficient 7. Between these two curves and the C. B. and Q. curve there is a maximum variation of but 22%, considering areas between 100 and 1,000 square miles.

The methods employed in railway culvert and bridge design are sound. Continued careful work in observing and recording high water marks at existing structures and the recording of characters and areas of drainage basins will tend toward the lessening of washouts, and greater economy in bridge and culvert design.

The forms and instructions for engineers, exhibited in Mr. Bremner's article, which he uses in collecting data for each individual bridge and culvert to be renewed with permanent structures, must be commended for their completeness in covering the salient points. They are worthy to be accepted as standard forms on all railroads.

*Mr. Edwin Duryea, Jr.*— M. W. S. E. (*by letter*)—On the railroad work done by the writer, all of it more than fifteen years ago, the culverts and small openings were proportioned mainly by guess on intuition. The methods described by Mr. Bremner, Mr. Dun and Mr. Kingman are immense advances on this and must result, on the average, in structures proportioned much nearer to their respective duties and in much saving, because both of washouts prevented and of the avoidance of structures of excessive size and cost.

Their practice, however, could be still greatly improved by adopting a more rational method. As noted by Mr. Alvord, fixing the area of opening by the area of the tributary drainage-area is irrational, and confuses the problem by linking together two parts of it—the runoff or flood-yield of the drainage-area and the conduit-capacity of the opening, which have no connection with each other. A logical solution would require that first, as careful an estimate as practicable, be made of the flood-flows and second, that the opening be proportioned by usual and well known methods to carry such flows.

While it may not at first seem so, such a logical method would not require much additional work. A first approximation to the flood-flow can be made by assuming a rate in cu. ft. per sec. per sq. mi. of drainage-area. The survey, which must in any case be made for the opening, will give cross-sections of channel and height and slope of high water marks. From these data and an assumed coefficient of roughness, a few minutes work with a diagram will give at the same time the approximate flood-discharge of the drainage-area and the carrying capacity of the natural channel.

From the survey data the channel may be rated for its approximate discharge at different depths of water and a few observations on floods of various heights, after the railroad is completed, will serve to check or correct such a rating-curve and give more exact information for proportioning a future permanent structure or for use in other localities. Approximate measurements of floods may often be made in a few minutes by a single person. A short course should be chosen, one or two hundred feet long and of as uniform conditions as can be found, and the maximum surface velocity as determined by floats or chips and the second-hand of a watch will, when multiplied by 80%, generally give a fair approximation to the true mean velocity. The cross-section of the flowing water can be estimated from more or less complete measurements and sometimes from the known cross-sections of the stream, locating the water-surface from the railroad grade-line. The writer has sometimes secured valuable information which would otherwise have been lost by measuring the breadth of a stream by revolutions of a wagon-wheel, its depth by immersion on the spokes, and its surface velocity by chips and a paced course. In regular cross-sections, a rough approximation to area will be the surface-width multiplied by two-thirds the maximum depth. Such rough methods are not recommended when better ones can be availed of, but in emergencies they may be of great value. It would seem that even such methods would add considerably to data applicable to the proportioning of culverts and small railroad openings. They would certainly give data of value not only in railroading, but also in other fields of engineering.

It is of interest to see how greatly the neglect of all but the *area* of the opening may affect its carrying capacity. The ordinary formula for flow in open channels is:

$$Q=AV=A\times(C\sqrt{r\ s})$$

with $Q$=discharge in cu. ft. per sec.
$V$=average velocity.
$A$=area of water-way.
$C$=a constant, depending on experiment.
$r$=hydraulic radius=area÷wetted perimeter.
$s$=slope of conduit.

When only A is considered, evidently C, r and s are neglected.

Let an opening be assumed of 40 sq. ft., in various shapes. Then if

3 ft. deep by 13 1-3 ft. wide, $r=40\div19\ 1\text{-}3=2.07$ and $r=1.44=97\%$.
4 ft. deep by 10 ft. wide, $r=40\div18=2.23$ and $r=1.49$ 100%
5 ft. deep by 8 ft. wide, $r=40\div18=2.23$ and $r=1.49$ 100%
7 ft. deep by 5 5-7 ft. wide, $r=40\div19\ 5\text{-}7=2.03$ and $r=1.43=96\%$.

From the above it is apparent that while the flow will be greatest for a depth of 4 ft., or 5 ft., still it will be reduced only 3% or 4% for depths of 3 ft., or 7 ft. The neglect of the shape of the opening is therefore not serious in its results.

The neglect of slope, however, is much more important. If the probable limits of such slopes are assumed as ¼ ft., and 2 ft. per 100 ft., then for

$s=0.0025$ ft. $\sqrt{s}=\sqrt{0.0025}=0.05$ 36%

$s=0.02$ ft. $\sqrt{s}=\sqrt{0.02}=0.14$ 100%

and the discharge due to the flatter slope will be only about a third that due to the steeper.

A consideration of the co-efficient "C" is more complicated as the co-efficient includes not only the effect of roughness, but is also affected by the slope and the hydraulic radius. However, if extremes are assumed of

(1) $r=2.07$, $s=0.0025$, $n=0.035$ and
(2) $r=2.23$, $s=0.02$, $n=0.020$

then by Mr. Alvord's diagram

(1) $C$ = about 45 = 55%.
(2) $C$ = about 82 = 100%

It therefore seems that two openings, each 40 sq. ft. in area but of different shapes, slopes and roughnesses may compare in carrying capacity as follows:

(1) $97\%\times0.36\times0.55=19\%$.
(2) $100\%\times1.00\times1.00=100\%$.

or that one of the openings may have 5 times as great a velocity and carry 5 times as much water as the other. The respective velocities will be:

(1) $V=C\sqrt{r\ s}=45\times1.44\times0.05=3.24$ ft. per sec.

(2) $V = C\sqrt{r\,s} = 82 \times 1.49 \times 0.14 = 17.10$ ft. per sec.

Neither of these velocities is inconsistent with flood conditions or beyond the limits met with in actual measurements by the writer. The irrationality of taking into consideration only the area of the opening, or of using an assumed uniform velocity of 10 ft. per second, is apparent.

It is worthy of remark, however,, that while Mr. Dun's method is irrational (taking into account only the *area* of the opening and fixing that directly from the areas drained) still the curve plotted from his areas of opening with an assumed uniform flood-velocity of 10 ft. per sec. is preferred to Mr. Murphy's curve by at least two advocates of rational methods—Mr. Alvord and the writer. Mr. Dun's curve shows the good results which may be secured by empirical methods when used with good judgment and based on abundant and accumulating checks. His table in letter and his curve as plotted by Mr. Alvord are for Missouri and Kansas conditions.

For over three years past an important part of the writer's work has been the organization of stream-flow measurements on a number of California streams. These measurements have been continuous and were made with great care and accuracy. The greatest flood-rates actually occurring in this period were 140.0 cu. ft. per sec. per sq. mi. from 22.2 square miles of drainage-area and 93.8 sec. ft. per sq. mi. from another drainage-area of 67.7 square miles. These two rates occurred in different years. Both these drainage areas are in the Mt. Hamilton range of mountains, (Coast Range) in Santa Clara county, California. The larger is very precipitous, with steep slopes rising from the edge of the stream; while the smaller, though mainly steep slopes, has broad mountain meadows bordering the stream. The mean annual rainfall is about 34 inches for the smaller and 28 inches for the larger area and the vegetation (at least by eastern standards) is scattered and somewhat sparse.

The maximum measured rate of flood-flow in a 193.2 sq. mi. drainage-area (of which the 67.7 square miles form a part) is 78.5 sec. ft. per sq. mi. from the same flood which gave 93.8 sec. ft from the 67.7 sq. mi. on one of the tributaries. Careful surveys of maximum high-water marks (floods of 1884) indicate that the maximum discharge at that time may have been 148 sec. ft. per sq. mi. from this 193.2 square miles.

Careful studies using above data, considerations of rainfall, etc., convince the writer that in the Mt. Hamilton Range it is inadvisable to proportion the spillways of dams for less than 200 sec. ft. per sq. mi. of drainage-area, even for areas as large as 200 sq. miles.

Other studies for the design of a dam on the South Fork of Eel River, in Mendocino county, California, convince the writer that spillway capacities should there be provided for rates of flow of 300 sec. ft. per sq. mi. The flood-data was much less complete for the Eel River than for the Mt. Hamilton drainage-areas, but consisted of actual measurements of three low floods and an accurate

survey of the highest visible flood-marks. These, considered in conjunction with a mean annual rainfall of perhaps 474 inches and a maximum of probably over 70 inches, the known presence of quickly melting snow, and the nearly circular shape of the drainage-area, led to the adoption of the 300 sec. ft. per sq. mi. The drainage-area is in the Coast Range Mountains, in Lake and Mendocino counties, comprises 324 sq. miles, and varies in elevation from 1400 ft. above sea at the damsite, to 5000 ft. to 7000 ft. on the summit-line of the encircling mountains. The dam was designed and its construction began last summer and only a few weeks ago its uncompleted masonry portion safely passed a flood of about 50,000 sec. ft. or 155 sec. ft. per sq. mile.

In Frizell's "Water Power" 3rd edition, 1905, p. 43, is given a very interesting table of maximum flood-flows in sec. ft. per sq. mi. This table gives observed rates of 100 sec. ft. per sq. mi. from 386 sq. miles; 265 ft. from 116 sq. miles; 366 sec. ft. from 20.1 sq. miles; 828 sec. ft. from 6.1 sq. miles and 1015 sec. ft. from 3.6 sq. miles. These drainage-areas are all in Germany. The maximum flood-rate during the Johnstown flood is also given, it being 206 sec. ft. per sq. mi. from 48.6 sq. miles.

On his p. 41 Mr. Frizell gives a formula for maximum rates of floods, based on the Connecticut River run-off (a maximum observed flood-rate of 17.35 sec. ft. per sq. mi. from 8006 sq. miles), which agrees fairly well with the observed values of his table. His formula is

$$Q = 17.35 \sqrt{\frac{8006}{A}}, \text{ with}$$

$Q$=maximum flood rate in sec. ft. per sq. mi.

$A$=square miles of drainage-area.

Comparing this formula with the writer's measurements and conclusions, the formula gives

for $A=22.2$, $Q=330$ sec. ft. per sq. mile.

for $A=67.7$, $Q=189$ sec. ft. per sq. mile.

for $A=193.2$, $Q=112$ sec. ft. per sq. mile.

for $A=324$, $Q=86$ sec. ft. per sq. mile,

as compared with the writer's measured flows of—

from 22.2 sq. miles, 140.0 sec. ft. per sq. mile,
from 67.7 sq. miles, 93.8 sec. ft. per sq. mile,
from 193.2 sq. miles, 78.5 sec. ft. per sq. mile,
from 324 sq. miles, 155 sec. ft. per sq. mile,

and his conclusions from maximum flood-marks, etc., of—

from 200 sq. miles, 200 sec. ft. per sq. mile,
from 324 sq. miles, 300 sec. ft. per sq. mile.

This apparently illogical conclusion, the higher flood-rate from the larger drainage-area, helps to bear out Mr. Alvord's comment that no general formula, unmodified by judgment, can be depended on to give safe flood-rates in specific cases. This was well brought

out in his discussion on "Excessive Precipitation at Chicago," of which paper the writer was the author.

Mr. Frizell's general formula.

$$Q=Q_1\sqrt{\frac{A_1}{A}} \qquad Q=Q_1\sqrt{A_1}\div\sqrt{A}.$$

seems a very convenient one for utilizing flood-rates observed on one drainage-area, in the study of other drainage-areas of similar characteristics. The maximum flood-rate and area of the observed drainage-area are represented respectively by $Q_1$ and $A_1$ and those of the area being investigated by Q and A.

Mr. Bremner deserves the thanks of the profession for his valuable paper. While the value of a paper is much increased by the discussions it brings forth, it is the writing of the original paper which requires initiative and energy and the author is entitled to credit not only for his own paper, but to a considerable degree for the discussions also.

*Mr. Arthur N. Talbot*— M. W. S. E., by letter —The writer has been interested in the topics of this paper for a number of years, and in 1887 he wrote an article on "Waterways for Bridges and Culverts" which was published in No. 2, "Selected Papers of the Civil Engineers' Club of the University of Illinois." In this article was given a formula for waterways, which has since been used quite extensively by railways, and also a formula for flood flow of streams and a method for determining the discharge of stream and the necessary span length for bridges. It is interesting to see that so much more information is given in the present discussion than was then avialable.

There are two phases of this problem,—(1) the determination of the quantity of water which may flow from a given drainage-area, and (2) the selection of the size of water opening. For the smaller drainage-areas, the size of waterway may be selected directly and without calculating the flood discharge, but for streams of any magnitude, it is best to estimate the discharge, determine the velocity which may be expected at the given point, and in other ways take into account local conditions in calculating the requisite waterway. In this discussion the determination of the flood discharge will first be considered, and methods of getting at the requisite waterway will then be taken up.

All recognize that the determination of the runoff of streams is a complex problem involving many variables. Conditions vary, and in the same stream there may be a question concerning what weight should be given to extraordinary storms occurring at very long intervals. The general solution by making use of all available data of observed runoff is a good one, and the diagram (Fig. 11) given by Mr. Alvord showing recorded runoffs and proposed formulas is valuable for comparison. The writer's formula for flood discharge in small rivers of average slope given in the article in

"Selected Papers of the Civil Engineers' Club of the University of Illinois" before referred to is:

Flood discharge $=$ 500 cu. ft. per sec. per sq. mi. $\div \sqrt[4]{\text{Area in sq. miles}}$.

It is believed that this formula gives results which cover all but extraordinary floods in streams of moderate fall in our prairie states for areas up to say 200 sq. mi. It was not intended for use beyond this limit.

After considering and comparing the various formulas proposed, it seems to the writer that the formula given by E. C. Murphy does not make sufficient provision for the large floods which permanent railroad bridges should be expected to take for the drainage areas less than 200 sq. mi., and that its results for areas less than 200 sq. mi. will give openings much less than provision should be made for except in very flat prairie country. On the other hand, the writer is convinced that the values given by Mr. Dun's formula for drainage areas less than 50 sq. mi. are larger than necessary, except where steep slopes and cloudbursts combine to give large runoffs. For areas less than 50 sq. mi., the values given by Mr. Bremner seem more reasonable, though the C. B. & Q. curve runs low for large areas. The wide divergence in the formulas quoted shows the difficulties of the problem, and not only must the local conditions of the stream be studies but the judgment of the engineer must in the end temper the results.

It is sometimes possible to determine flood runoffs from high-water marks, cross-sections, and the hydraulic gradient of the stream, and calculating by formulas like Kutter's formula, but this requires considerable information, care, and general hydraulic knowledge. If it can be done properly, the results will be more trustworthy than those obtained by a general formula. For any important bridge opening it will be well to undertake such an investigation before deciding on the span.

The velocity of the current through the bridge opening will vary over a wide range. So much depends upon slope, depth, and condition of channel that a general value can hardly be selected. Frequently back-water in the stream below reduces the available hydraulic slope and limits the velocity at the opening. Generally, however, a wise choice of the channel site and a little work in changing the channel above and below the opening will make a higher velocity available than the average velocity of the stream. The velocity most used in the papers and discussions is 10 feet per second. For the larger openings in flat prairie country it is doubtful whether a velocity of 10 ft. per sec. may usually be obtained, but in broken and hilly country, the stream velocity during flood seasons may considerably exceed this amount. For the more important openings a careful estimate of the value of the velocity at flood times, in the light of all the available data, should be made.

For the smaller and less important openings, say with drainage area up to 10 sq. mi., or in flat country even up to 50 sq. mi., it may be feasible to consider that a certain velocity is available and thus modify the formula so as to give the area of the opening directly. The papers under discussion have used 10 ft. per sec. for this general velocity. For these smaller waterways, if the opening is not liable to become obstructed a velocity of 10 ft. per sec. may be obtained, even when a slower velocity like 5 ft. per sec. exists in the stream above, by permitting the water to head up 1.5 or 2 ft. at the entrance to the culvert. In the formula proposed by the writer in No. 2 "Selected Papers," a smaller velocity than 10 ft. per sec. was used. This formula, recommended for culverts is, "*area of waterway in sq. ft.* $= C\sqrt[4]{(\text{Drainage area in acres})^3}$; using a value of C equal to 1-3, gives results lower than the formulas given by Mr. Dun and Mr. Bremner; but reports from the use of this formula show that for territory like the flatter part of Illinois, such sizes have proved to be inadequate. For steeper, rolling country values of C equal to 0.4 and 0.5 have given sufficient waterway.

Not enough importance is generally attached to the shape of the stream channel above and below the bridge opening. Not only should the channel be cut to form an inlet of proper shape above the bridge or culvert to facilitate the change of section from the ordinary channel to that of the opening, but the enlarged opening should extend downstream until the flood water has a chance to escape over the flat below without obstructing the current and impeding the velocity through the bridge opening. A comparatively small sum spent on improving the channel of the stream will in many cases add materially to the discharging capacity of the bridge opening. This is a matter which is frequently overlooked.

It may not be out of place to add that the discharging capacity of culverts, when running under such conditions as not to flow full bore at the lower end, is materially less than that calculated by the usual hydraulic formula. This is due to the dropping of the water in the contraction at the entrance to the culvert. In order that a culvert may flow full and discharge the amount calculated by the ordinary formula for short pipes, either the hydraulic head on the center of the pipe must be at least one diameter, or there must be backwater causing the outlet to be submerged. For railroad culverts, contrary to a prevailing notion, there is little difference in the discharging capacity, whether constructed with wing-wall entrances at one angle or another, or with straight abutment walls. Wingwalls may be advantageous in directing the flow of drift and rubbish through the culvert. From a hydraulic point of view, a conical mouthpiece at the lower end of the culvert, arranged so that the diameter is increased, say 40% in the last diameter length of the culvert, would give a larger discharge, and possibly such a construction might be advantageous in long culverts.

*Mr. Albert J. Himes*—(*by letter*)—Though I have no new formula to suggest, there are two topics pertaining to the subject of the paper to which I would call attention. The first is the use of the stadia in securing the necessary data concerning the area and slope of a water-shed. The rapidity and ease with which such data may be secured by this means seems never to be appreciated by men who have not used it, and the obstacles seem to be that railroad engineer corps are seldom equipped with good stadia rods and charts and that an inexperienced man does not secure the best results on his first attempt. The final economy is sufficient to well repay a few days' drill and it can be confidently stated that every railroad engineer corps should be so equipped.

It seems hardly worth while to undertake a description of stadia work as it has been exhaustively discussed in the Engineering News, the Transactions of the American Society of Civil Engineers, and by Mr. W. C. Bunnell, in the Journal of this Society.* A careful reading of Mr. Bunnell's paper will show the merits of the work and although Mr. Bunnell had no railroad experience, and on that account may not be considered an authority on the subject, it will give confidence in his opinions if I say that he received his training in stadia work from Mr. E. E. Hart, now Chief Engineer of the N. Y. C. & St. L. R. R. If railroad men have any doubt about the economy of the method and its adaptability to their needs, it would be well for them to write Mr. Hart.

The second has to do with the construction of openings under the track. It is refreshing to note the extended use that is being made of hydraulic knowledge in determining the size of waterways. The days when "To give, guess and allow" constituted the art of engineering, are fading rapidly into the past, with a resultant economy of construction and increase of dividends. But I have often wondered why we should stop with the determination of the area of the waterway and not apply our knowledge of hydraulic construction to the structures. In hydraulic works the prevention of leaks and scour are of the first importance and have been given years of study by hydraulic engineers. The use of puddle, cut-off walls, sheet piling and paving are standard practice in canal and reservoir building and why not use these things where railroad work touches the hydraulic field.

Mr. Dun notes some floods that exceeded the limits of his table by 200% to 300% and says that such occurrences are so unusual that it does not pay to provide for them. It is true that to provide openings large enough to discharge so much water readily is impracticable, but in building arches and abutments for short span bridges, if consideration were given to the effects of excessive floods, the structures might be built to stand even though submerged.

It would seem that where rock foundations do not exist and great floods are known to occur though at long intervals, it would

*Vol. VIII, p. 527, 1903.

be economical to build openings to withstand the greatest floods that might come against them. The increase in cost of such construction would not be great and the avoidance of the expense and interruption of traffic incident to a washout would easily jusify it in a great many cases.

It is not uncommon to found masonry upon coarse gravel at some depth below the bed of the stream. Such practice is not objectionable if the stream is not subject to scour, but who shall say that there will be no scour? In a case of this sort, a structure considered by everyone having any knowledge of it, to be perfectly safe, was badly wrecked not long ago, by the formation of an ice-gorge which caused the level of the water to rise and create a head sufficient to undermine the masonry. A good row of sheet-piling around the foundation and a paved channel might have prevented the disaster.

The volume of water to be discharged through an opening, is not the only factor in determining its size. Where the Erie and the D. L. & W. railroads skirt the base of the Allegheny Mountains, numerous small streams often discharge, during a heavy storm, great quantities of gravel and the Erie Road has been tied up completely for many hours by banks of gravel deposited on its tracks by these streams. The care of this shifting gravel is a very perplexing task and in some cases seems hopeless. Settling basins or ponds are sometimes built above the tracks; sometimes where the grade line is high above the natural surface and the fall of the channel very rapid, the gravel may go through the opening, but these conditions do not always exist and where they do not constant labor and watchfulness seem the only protection. It is possible that in some cases, the use of large cast iron pipe might lessen the trouble. The inside of the pipe is so smooth that water and gravel would shoot through the opening with great velocity and no tendency toward clogging would exist.

## CLOSURE.

*Mr. Bremner*—The matter of drainage might properly be divided into three classes:

First—Drainage cared for by sewers.

Second—Drainage cared for by large streams and requiring large bridge openings.

Third—Smaller streams or "draws" usually provided for by small culverts and pipes.

The first two of these classes should be provided with an opening of the maximum size to provide for flood water as so well covered in the discussion of the paper.

The third class, smaller bridges and culverts, can not be so well provided for by a formula, for the reason that it is not always necessary to take care of the maximum flow of water at once, but that frequently the water can be dammed up a limited amount, and thus time be allowed for the water to flow off, sometimes under a

head. This cannot be the case in the first two classes, and this is not always the case with the smaller bridges. There are frequently cases where the maximum flow has to be cared for the same as with the others. It is for this reason that the personal judgment of the engineer is such a large element in the selection of the size of openings for this class of waterways.

All who have joined in this discussion seem to be united in regard to one thing,—that is, we have all reached the conclusion that common sense, in applying a formula, is the main ingredient. One should have had more or less experience in this work, before he can definitely tell how to use any formula. It would appear that nearly any of these formulæ, with a sufficient amount of experience, could be used quite intelligently by our engineers.

A few years ago our company was using an arbitrary system of putting in iron pipes. Iron pipes vary from 18 inches to 7 ft. in diameter and we were given arbitrary drainage areas that we could use for these sizes of pipes. This method was used for a great many years and it was quite satisfactory, for the smaller openings. For the larger openings the formula $Q=\sqrt[3]{A^2}$ referred to by Mr Cooley, was used, and it has been only recently that we changed from that formula; and in fact, we have not yet dropped it altogether.

The sizes of pipes which were thus used were not at all consistent with each other and with our practice in regard to larger openings. Upon investigating various formulæ, it was found that nearly all or many of them, gave openings which were a great deal in excess of what we knew we could get along with, from our experience for years in the arbitrary areas we had been giving to our pipes Looking still further into the matter, the conclusion was reached that the Fanning formula, which is used in the inset ($A=25\ \sqrt[6]{M^5}$ for 8 ft. per sec. Fig. 4) shown in diagram for openings for the smaller drainage areas, applied with a variable velocity about fitted our experince. We have not used a fixed velocity in the formula for smaller pipes but a variable one increasing in velocity as the pipe increases in size. The openings appear to be smaller than are given by most of the formulæ for sewers or for overflows for reservoirs or for large drainage areas. It seems reasonable that we should use smaller openings in proportion to the drainage area for these culverts than sewers, reservoirs, overflows and for large bridges. A reservoir should have a large opening for its overflow on account of the chance of destruction of the dam. There should be a large waterway in sewers in a town which would be flooded if they were not made amply large. Likewise in big bridges, if the openings are not made large, in case of high water the bridge banks and everything would be washed out. But in a smaller drainage area the water can be backed up, in a great many cases, to a comparatively large amount. A variation of 10 per cent of

an opening of four to twenty square feet is a very small matter compared to the same ratio of increase in a large opening. Back-water from the former would be inappreciable, while from the latter it may be destructive. Consequently we can use a different ratio of openings and different formula for the smaller areas than for the large. We have every year a large number of these small openings to investigate. It will run from 300 to 600 in the territory east of the Mississippi River, and on account of the number, we need formulæ and tables which can be used quite readily. It is the practice to investigate the small bridges and fill them up as fast as we can. If we estimate on too large a pipe, we would probably be told by the management to rebuild the bridge; that the cost would be too great to allow getting the permanent openings. So if we can put in a smaller pipe or culvert with safety, it is advisable as well as economical to do it. Making too large an opening is unsafe as well as making it too small for the reason that it often leaves a pile bridge in the track.

A few years ago we had occasion to investigate the openings which had been made in our St. Paul lines between Oregon and Savanna. There were quite a number of these openings—about 175. They were originally put in by guess work, and at the time they were found to vary in relation to our formula, from 400% down to 25%. We had not had so very much trouble with those that were 50 to 75% of the size which the formula would give, but we had had some trouble with those that were only 25%, and we planned to rebuild a number of them. The damage that was done, however, was comparatively small after a very high flood which we had in that section of the country, and if these openings had been as large as the formula calls for we would have had no trouble whatever.

We cannot vary the size of the openings as much, on account of the country being hilly, or flat country, as we can on account of the shape of the drainage area. In the hilly country as a rule the embankment is higher above the opening and the water flows faster through the box or pipe. The proper way to put in an iron pipe of culvert is to put it in so there is a steeper flow through it than the slope of the valley. The up stream end to be above the bed of the stream, and the down stream end to be level with or below the bed of the stream. While I have used the word *pipe* mostly in regard to all our culverts, it is not customary to use pipe on all occasions. We are using reinforced-concrete arches and culverts and are experimenting with reinforced-concrete pipe, which will probably be our future small culvert.

Mr. Chamberlain's experience in regard to bridge openings seems to be very similar to my own in regard to putting in permanent structures. Instead of using a velocity discharge of 10 ft. per sec. the maximum discharge which we have usually figured on has been in some cases 9 feet, but usually 8 feet or less for small openings. I agree with the conclusion of Mr. Cooley and Mr. Merriam,

that in the smaller areas a larger run-off per acre should be provided for than in the larger areas. The formula which we have used for this discussion provides for this. The increase, however, is not in the same ratio as in most of the other formulæ in use, and which have been discussed above, and it is for this reason that we prefer it as explained.

Where close areas are needed the stadia method of survey, recommended by Mr. Himes, can be used, but usually extreme accuracy is unncessary.

Prof. Talbot's suggestion that we should properly line or channel the stream into and out of the opening is frequently followed. I think his suggestion in regard to the exit angle of the water is a subject well worth considering further, on account of the effect of the wash on the country below an opening.

The object of the paper was not to present or to discuss a formula, but the methods of applying one, and that is what our directions to the engineers consist of,—methods of applying the formula and using it; how they shall best direct their judgment in choosing an opening, and how they shall get the information together to choose from. I am not sure that those instructions are all right, and was hoping for extended criticism of them. I am very glad that the discussion has brought out so many valuable ideas.

# ELEVATING AND CONVEYING MACHINERY.

S. F. Joor, M. W. S. E.

*Presented February 21, 1906.*

In taking up this broad subject it will be necessary to narrow our consideration to special uses of the machinery where the designing Engineer is particularly interested. It may be advisable to divide the subject primarily into devices for carrying articles in bulk and for carrying packages of various kinds. In the latter class of machinery would be included apparatus for handling bags and blocks of stone and similar heavy units which are not really packages, but have to be handled in the same way.

Generally speaking, the advantage of elevating and conveying machinery is derived primarily by handling small quantities of small packages in rapid succession, making a practically continuous process, instead of loading up a greater bulk in carriers or cars such as are used for platform elevators and for the various types of cableway systems. As these methods of handling materials approach closely by degrees to the various forms of railroads, we will adhere in this discussion, to the continuous or semi-continuous process. Taking up the class of machinery for handling packages, the simple form of conveyor is furnished by the ordinary belt. This is made up of many different materials, for various purposes and depending upon whether a very cheap equipment or a very lasting form of belt is demanded, and also upon the amount of abuse which the conveyor will have to stand, either from the conditions under which it operates or from the material carried.

For handling light packages such as merchandise of the department store class, pouches of mail, bags of flour and similar material, the simple cotton belt is probably as lasting as any other type, and offers a cheap and efficient conveyor, but where the belt is to carry barrels, boxes and other packages which would break the fiber of the cotton belt, to obtain the best results it is necessary to use the highest class of rubber belts, protected by an extra rubber cover. This increases the cost of equipment very materially and makes it possible to substitute, to advantage, a chain device except where lightness is of material consequence. For portable work, the belt practically offers the only form of conveyor it is possible to use where heavy materials are to be handled.

Some of these have been installed in some warehouses in Columbus, in the East and also in Canada. The use of this is clearly shown by the cuts. In Fig. 1 is shown three separate units connected in line—two of them being on a level and the third raised

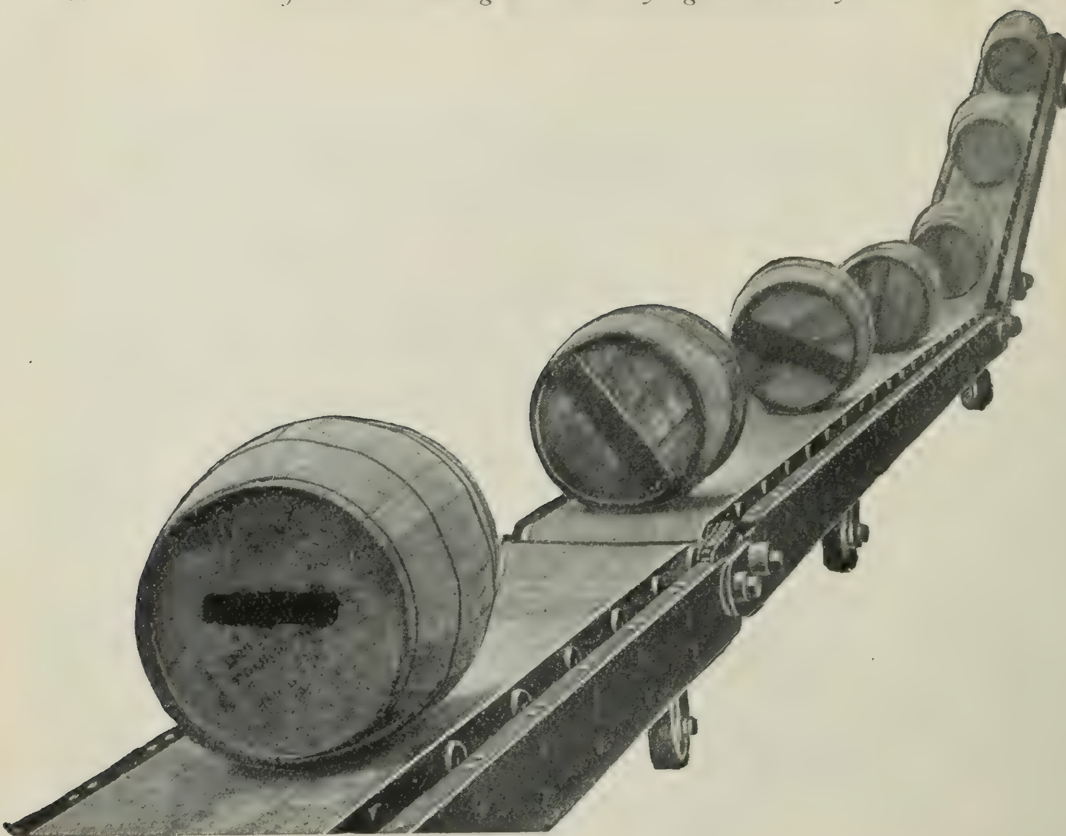


Fig. 1 .

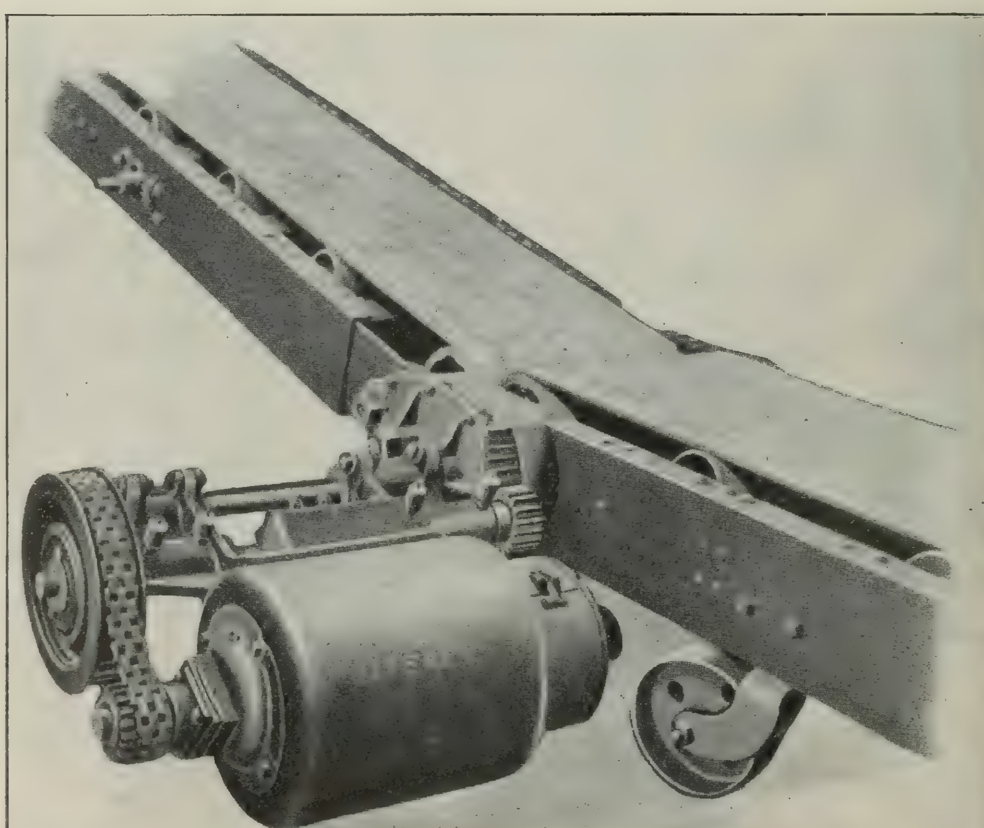


Fig. 2.

up an incline. Fig. 2 shows the drive mechanism which is used on one or more of the units, as may be necessary, according to the work to be done. The motors are intended to be strong enough to pull five or six sections for ordinary work; two men can shift one of these conveyor sections on any ordinary floor and the single section can be made up in length from 20 to 50 ft., the length depending more on the location of the columns in the warehouse than upon any other special feature. These conveyors are also adapted for handling materials in bulk, but they are especially designed for package work in warehouses and shipping rooms where it is necessary for the conveyor to be used in a number of places under varying conditions.

It is frequently possible to make stationary conveyors of the chain and wooden apron type, which will do practically the same work as the belt equipment just described and at much lower cost. The illustration Fig. 3 is from the Hoster Brewery of Columbus,

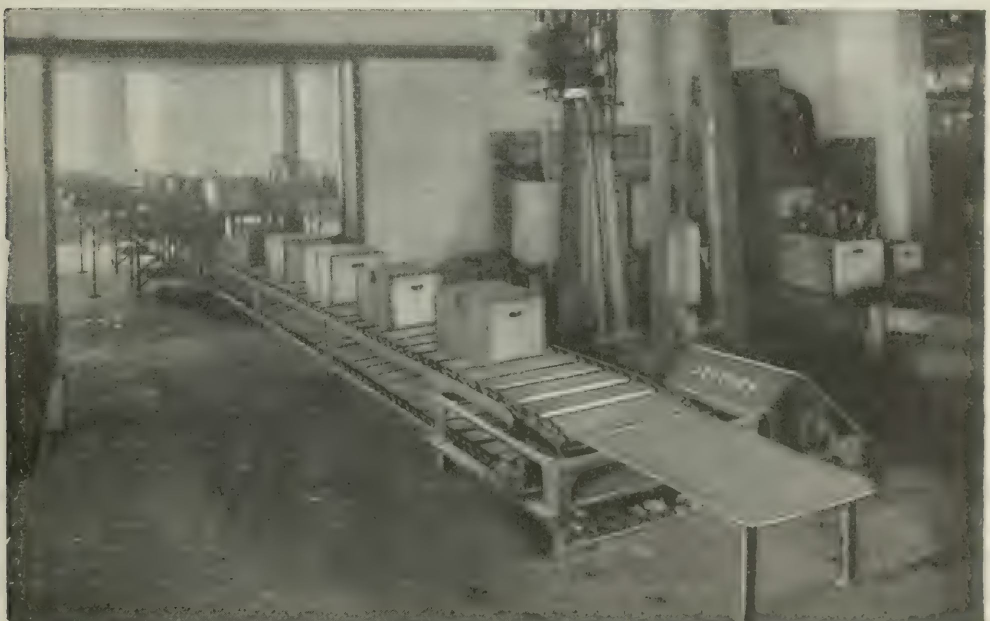
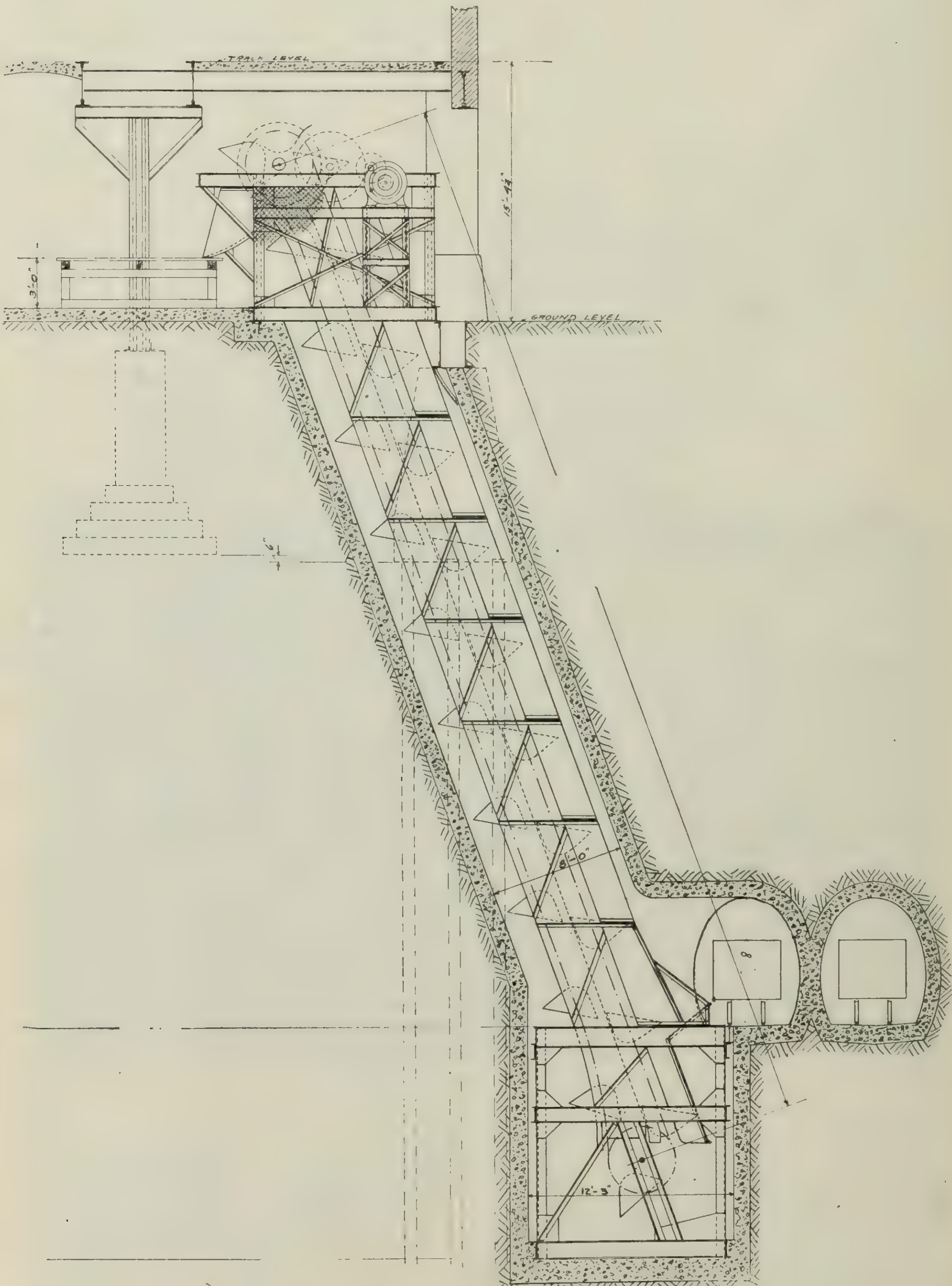


Fig. 3.

Ohio, and shows a conveyor running with cases of beer. Very frequently this type of conveyor is made up with the wooden slats from 4 ft. to 10 ft. apart and the polished steel or hard maple platform forms a table on which the slats slide the packages along instead of carrying them bodily. These conveyors can be run level or inclined, up to as much as 45 degrees. Where a steep inclination is necessary the surface must be arranged with raised pusher blocks to prevent the packages rolling or sliding down the incline. In constructing machinery of this class, roller chains are desirable only when the packages carried and the machine structure are light in weight. If heavy weights are to be carried or if the wooden apron




Elevator for Mail at La Salle Street Station.

itself is made of thick, heavy slats, it is much better to use either stationary rollers mounted on the frame or to have individual self-oiling rollers mounted at intervals on the slats, than to use ordinary roller type chains. An exception may be noted where long-pitch high-class steel chains are used instead of the malleable iron chains in ordinary use.

Two very large conveyors of this type from the tunnels of the Illinois Tunnel Co. to the track floor of the Union passenger station are being installed. There the chains are of 12 in. pitch, steel-bar links carrying as a part of the chain, 4 inch flanged chilled rollers adapted to oil themselves and the chain automatically and to carry the entire load borne by the hard maple carrying surface. These conveyors are shown in the drawing Fig. 4* and the structure of the chain is worthy of note. It is composed of two ½ in. by 2½ in. steel bars with a hardened steel bushing keyed into the side bars, making the links up into a unit. On the outside of this steel bushing, the 4 in. flanged self-oiling roller turns. The roller itself is chambered out to hold approximately a half pint of lubricating oil and in the oil chamber two fingers are cast which pick up a few drops of oil twice in each revolution and drop the oil upon a felt ring between the two flanges on which the wheels turn. This felt ring does not turn with the wheel and consequently does not become glazed by friction on the steel and continues to transmit the oil for an indefinite time, which it would not do if it turned with the wheel. The felt ring spreads this oil on the outside of the bushing and in this way produces a continuous clean lubrication for the roller; besides this, the bushing being drilled at intervals underneath the felt ring, oil is carried through from the felt ring, to the articulation of the chain and this also receives a continuous flow of clean oil from the center of the bearing outward to the ends, removing all grit which would otherwise work into the bearing and cause a rapid wear of the pins and bushing. These rollers will run for six months without any attention whatever but can be easily oiled at the end of that time. All rollers of this type can be satisfactorily used in the chains of heavy apron conveyors but without some equivalent oiling device, the carrying rollers will always become worn flat on the sides and cause a rapid increase in the amount of power required.

Apron conveyors of this type are more especially useful where the packages to be carried vary greatly in size and weight. If the conveyor is only to carry packages of one class it is usually cheaper and more satisfactory in every way, to use some form of carrying tray or arm as illustrated in Fig. 5, which is an inclined conveyor, carrying bags of flour. The trays or arms are made up in a very great variety of forms, some of them swinging freely between guides and adapted to pick up or discharge the material carried, at any one of a number of floors. The simpler types have merely the arms of the inclined form changed to suit the various conditions.

*This cut not received in time for this paper.

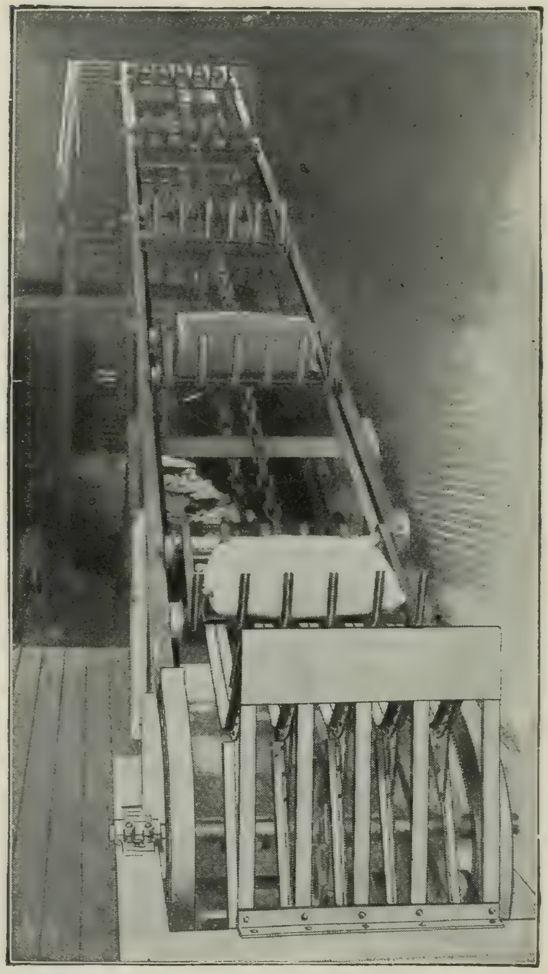
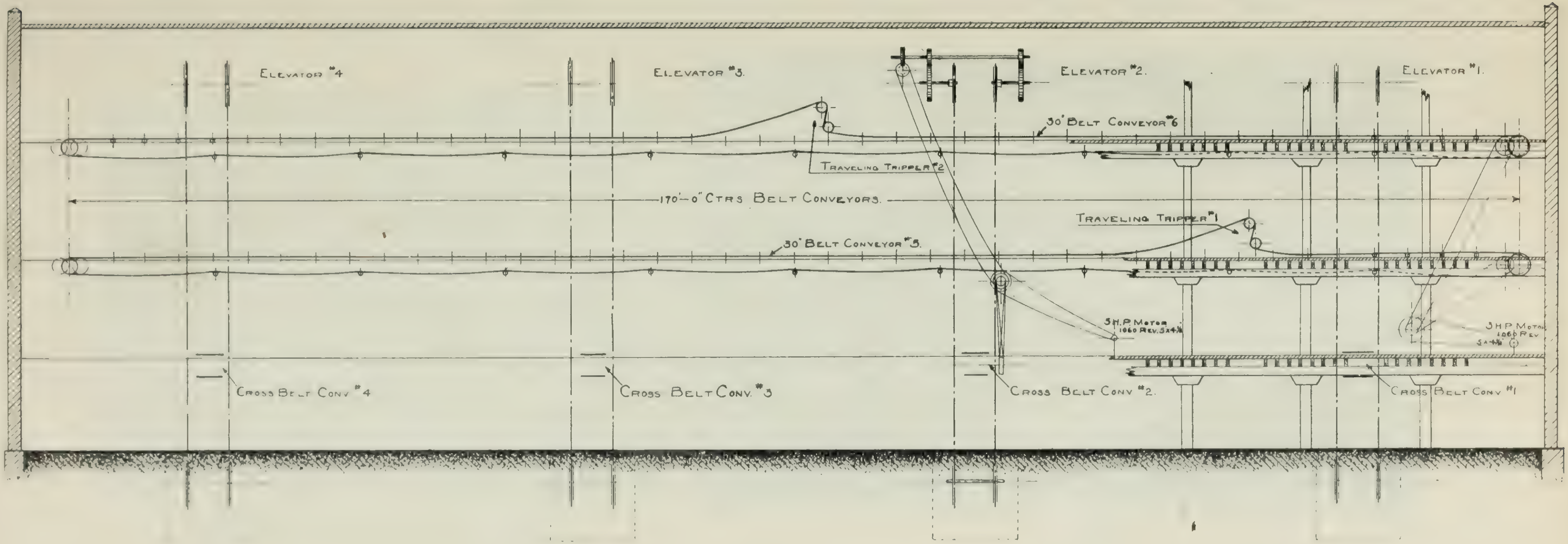


Fig. 5.

A large swinging tray elevator and a flour mill warehouse equipped with belt conveyors operated in connection with the swinging tray elevator is shown in Fig. 6. The equipment consists of four swinging tray elevators adapted to deliver materials either going up or coming down, at any one of the floors, and besides these four elevators on each floor there runs one large, reversible cotton-belt conveyor with a reversible tripper, permitting the belt to load or discharge at any point throughout its length, and adapting it to carry materials in either direction as required. The trippers are adapted to raise the bags of flour sufficiently high to discharge them to a distance of from 6 to 8 feet from the conveyor; at one or two points there is an arrangement by which the flour bags are discharged in the chutes leading down to lower floors, the elevators being used for lowering barrels only, but adapted to elevating both sacks and barrels.

Ordinarily in docks or railroad warehouses, conveyors are required of such length that a satisfactory equipment is frequently despaired of by railroad engineers. In ordinary practice chain con-



Elevator #4
Elevator #3.
Elevator #2.
Elevator #1.
30" Belt Conveyor #6
Traveling Tripper #2
170'-0" Ctrs Belt Conveyors.
Traveling Tripper #1
30" Belt Conveyor #5.
5 H.P. Motor 1060 Rev. 5x4½
3 H P Motor 1060 Rev
Cross Belt Conv #4
Cross Belt Conv. #3
Cross Belt Conv #2.
Cross Belt Conv #1


Fig. 6.

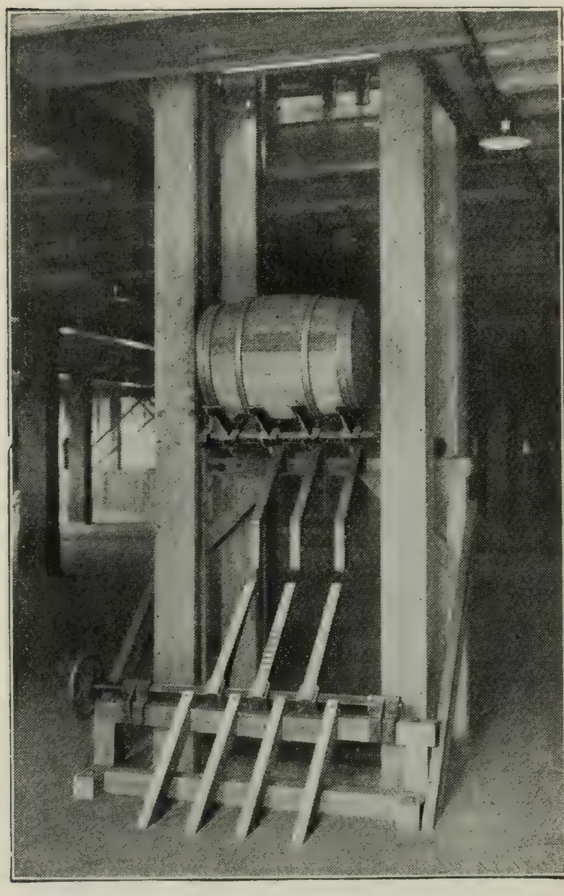


Fig. 6a.

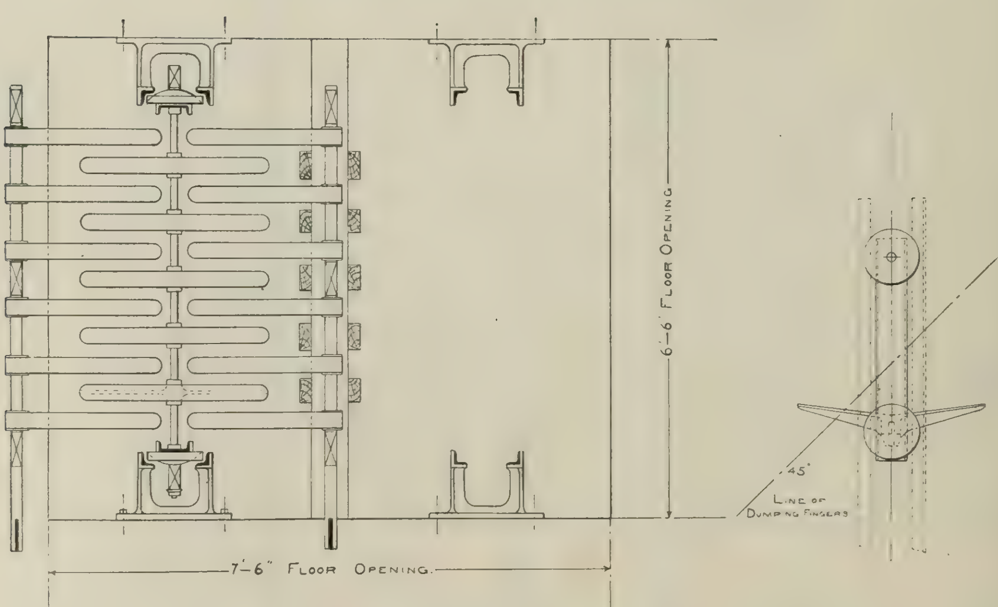

6'-6" Floor Opening
7'-6" Floor Opening
45°
Line of Dumping Fingers

Fig. 6b.

veyors and belt conveyors for handling materials of any considerable weight must be limited to not over 500 ft. in length, to be a commercial success, and as most freight houses require a greater length than this, to derive any large economy from the use of a conveyor system, most railroads have abandoned the idea of fitting any such equipment to their freight houses.

We have recently devised a type of conveyor which can be used practically in any length, and we are at present designing a system operating through a distance of 10,800 ft. The conveyor itself is 5,400 ft. centers and is adapted to carrying both ways, to be loaded at 24 different points, to discharge automatically at 40 points and allowing a selection of the materials carried so that loading and discharging may be carried on indiscriminately and simultaneously at different points, thus permitting the packages to be discharged in

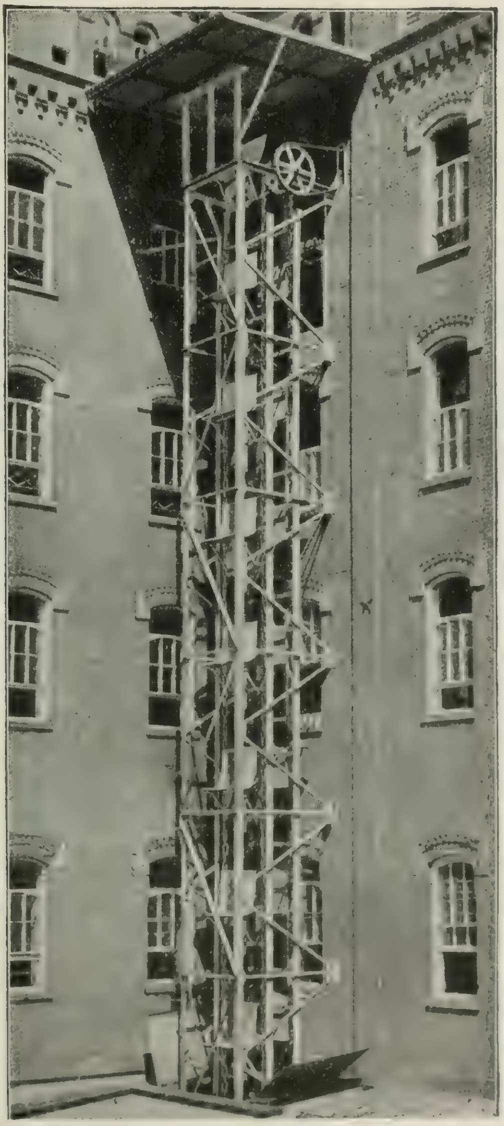


Fig. 6c.

all cases at the right place and carried by other discharge points. The system only requires a man or boy at the discharge point to throw the trip lever at the time a tray carrying a package marked for his station approaches him. Immediately after the discharge the empty tray is again automatically thrown in position and is ready to receive a new cargo at the next loading point which it passes. A man is stationed at the loading point who tags the package or the tray with the number of the station at which it is to be discharged and the conveyor itself does the rest. The loading is accomplished automatically by means of a tilting chute which will retain the packages until the empty tray comes into position to be loaded; the loader discharging the load by gravity upon the tray and then tagging it for its discharge point.

One notable feature of this conveyor is that it can be run on curves of moderate sharpness, and its level can be changed at any time desired. The tractive power is supplied by a steel cable and the conveyor can be made 10 miles long if desirable. The conveyor operates at an elevation of from 15 to 40 ft. above the floor on which the packages are to be discharged, and from the various discharge trippers, curved shoots, adjustable in inclination to suit various materials, are arranged to discharge to the floor below. This type of conveyor opens up a very large field, which up to this time has been unable to get service from conveying machinery of any kind.

Of the class of conveyors and elevators adapted to handling packages, Chicago has a very unique example in its new Post Office. The pedestrian who finds his way obstructed by the 14 large boxes along the Dearborn St. side of that building does not realize that these are the doorway to the mechanical equipment which permits the handling of the mail matter on three floors instead of one as at the former Post Office. The equipment for handling the mail is really divisable into parts—the East section and the West section. The East section, erected along Dearborn St. consists of the boxes above mentioned which carry under them two-ton weigh-hoppers adapted to discharge the mail upon maple tables. The scales of the weigh-hoppers are fitted with recording beams and the weight of every wagon load of mail sent in the Post Office, is accurately determined and recorded and filed in the Post Office, and forms the basis of the cost for handling the mail matter under some conditions. From the tables on which the mail is discharged by the weigh-hoppers, it is loaded by hand onto one of the three conveyors running lengthwise under the sidewalk.

One of these, running northward from under the main entrance of the Post Office to Adams St. is shown in Fig. 7, which also shows the weigh-hoppers, the receiving tables and the manner of handling the mail to the conveyor in question. The conveyor itself consists of a rubber belt 36 in. wide, traveling at a speed of from 60 to 90 feet per minute according to the requirements of the service, and delivering the mail upon an inclined conveyor seen in the back-

ground, which operates at a speed of approximately 600 ft. per minute. The object of this high speed is to make sure that the bags will lie lengthwise of this inclined conveyor. The bags of mail in the discharge from the first conveyor, to this second conveyor are caught on one corner in all cases, and the high speed jerks this corner out ahead and thus lays the bag lengthwise of the belt of the second conveyor. A further result of this high speed is attained in the discharge of the high speed conveyor, onto one at right angles running westward from the sidewalk, to an elevator which is shown in Fig. 8. This cross belt is 48 in. wide and the high speed belt delivers the packages with sufficient momentum to throw the bag of mail entirely clear both of the belt on which it has been carried and the chute leading down to the 48 in. belt. The result of this high momentum is that the bag jumps entirely clear of all obstruction and falls squarely across the 48 in. belt. Once the bag is loaded accurately at right angles to this broad belt, the bag itself will deliver with certainty into the buckets of the elevator shown in Fig. 8. These elevator buckets are 40 in. by 54 in. and adapted to hold two bags of mail. The elevator in question is one of the largest which has ever been built of buckets and chain, and if used to carry coal would deliver 400 tons per hour with absolute

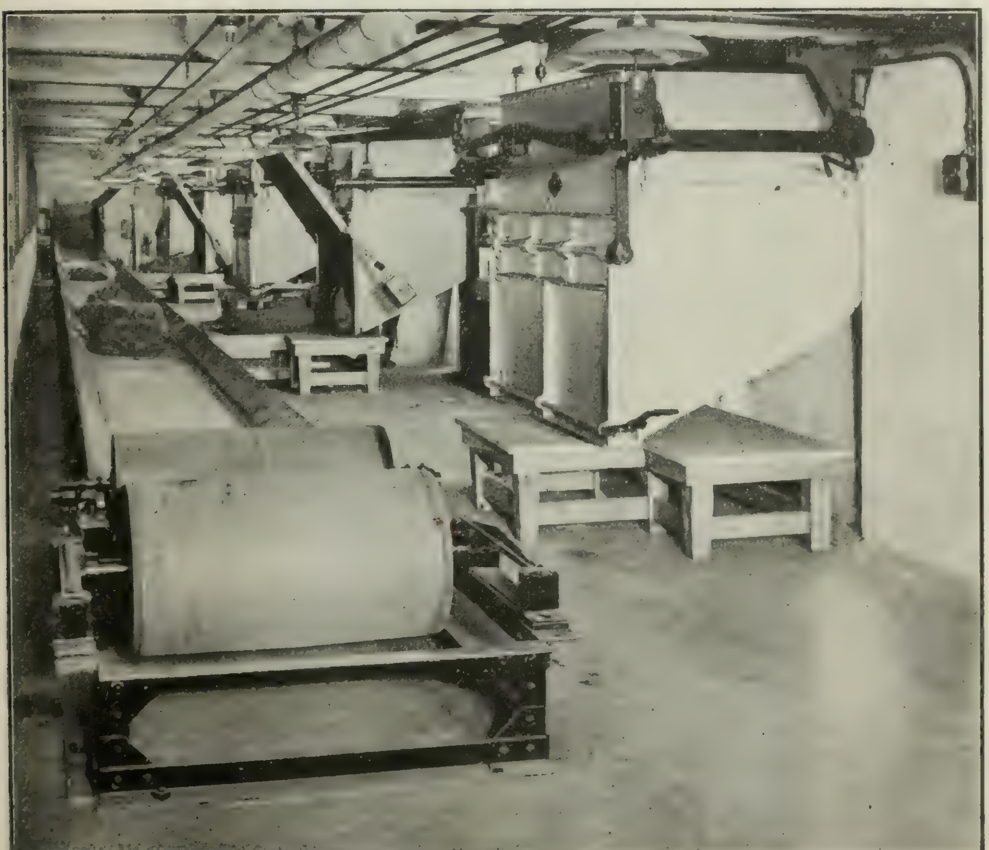


Fig. 7.
Belt Conveyer at P. O. under Dearborn Street Sidewalk.

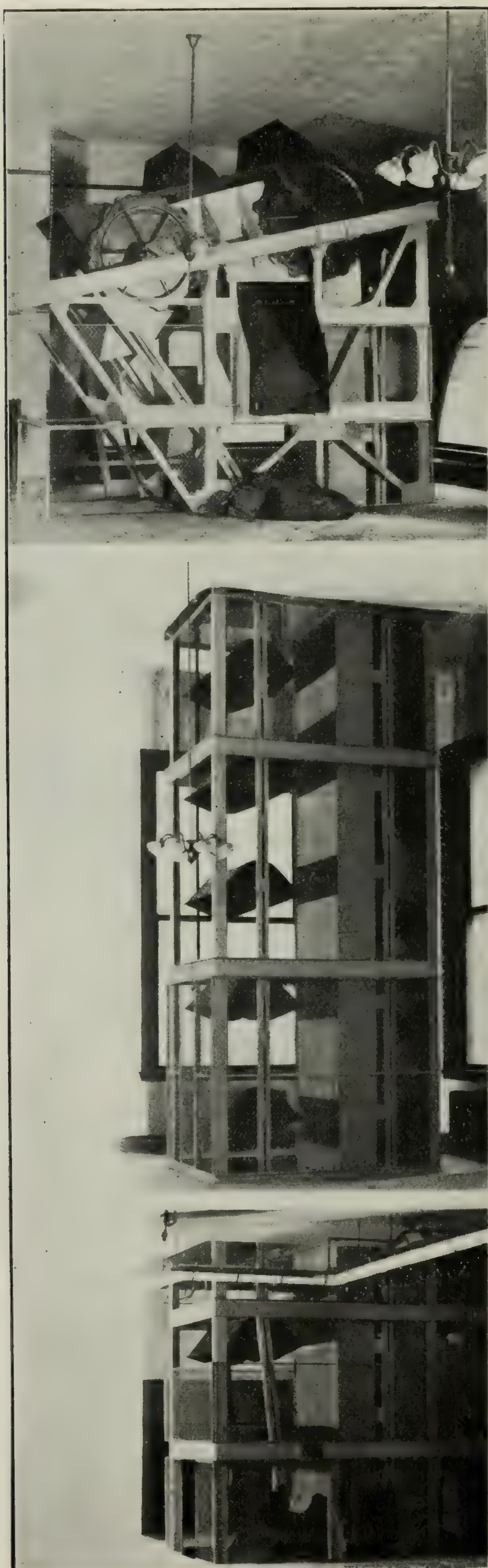


Fig. 8.
Elevator on 3 Floors at Post Office.

certainty, even at the slow speed at which it now travels. It is a somewhat unique proposition to handle packages in a bucket elevator, but on account of the strings on the bags of mail and the peculiar character of the package itself which is sometimes almost solid and sometimes very flabby, the bucket has proven more satisfactory than any form of finger or tray elevator could be for this work. These elevators discharge the mail on the second floor of the building where it is delivered to the state divisions. All three of the systems along Dearborn St. are practically alike.

Under the west half of the Post Office a drive-way is provided which was originally intended to take care of all the mail coming to the Post Office in wagons, but which has proven entirely inadequate at certain times of the day. For handling this wagon mail and for bringing into the Post Office the mail from the system of the Illinois Tunnel Co., with its connections at the various depots of the railroads, four elevators are provided of practically the same design as those on the east side of the building. These elevators have no belt conveyors in connection with them and some are adapted to discharge on the first floor and some on the second. For bringing the mail out of the tunnel a belt conveyor runs from the North end of the tunnel switch under the drive-way southward to the end of the horizontal drive-way in the Post Office basement. A part of this belt conveyor is at an incline, which allows it to discharge in a chamber above the tunnel bore and under the drive-way; here the mail is discharged to a crossbelt bringing it up to the mailing platform where the clerks divide the mail and send it to the various elevators as necessary. This last conveyor is 60 in. wide and is adapted to handle 300 bags of mail per minute.

All of the belt conveyors of the Post Office run on ball bearing rollers and have side curbs to keep the mail from falling off the belts, no troughing rollers being used on account of the additional height required for this construction.

The construction of the conveyors is somewhat more expensive than would ordinarily be used in commercial work and for this reason Consulting Engineers should not copy this construction for department stores and similar places, as has been done in several intances since the Post Office equipment was installed. Ordinarily a chain conveyor can be adapted to do the work in such places at much less expense.

The elevators in the Post Office have been mounted on 24 in. pitch steel bar-link chains with the keyed bushings and self-oiling rollers which were described in connection with the large apron conveyor for the Illinois Tunnel at the Union station. The length of pitch in these chains is the cause of the noise which has been so bitterly complained of by the clerks of the Post Office; but a long pitch chain or a secondary connection to the buckets was necessary to handle the very large buckets required on the elevators installed in this place. A shorter type of chain could have been used by using an expensive connection to the buckets, but in the close

competition demanded for this work and in the absence of any provision in the specifications such arrangement was not justified and the contractors were compelled to use the simplest device capable of doing the work safely. The government specifications permitted the simplification of a number of other parts of the system and by avoiding all the complications the contractors were enabled to reduce the cost of this equipment considerably more than 30 per cent below the figure at which the original designs could have been installed. At the time that this contract was let, there was a considerable amount of comment among conveying machinery engineers upon the large difference in the price quoted in our bid and in that of our competitors. The difference was due to this simplification and reduction of the number of parts in the equipment.

In connection with the noise in the Post Office, it may be worth while to state here, that no elevators of the size of the machines now in operation there, could be run without a very large part of this difficulty remaining. The structures are exceedingly heavy and are enclosed, in many places, partially or entirely, in heavy plate steel cases, which take up the vibration from the machinery and transmit it to all the floors. The real difficulty is that the Chicago Post Office has ceased to be a mere office, and has become a factory in which miscellaneous loose mail is manufactured into packages and distributed for points all over the country; and no factory operated by power can be run without some noise.

In taking up conveying devices used for handling articles in bulk, we find that the handling of grain and the handling of coal constitute probably three-fourths of the amount of work done by machinery or by hand labor, in this field. The amount of work done by machinery in handling articles loose or in bulk, although of enormous proportions at the present time, is but infinitesimal in comparison with the entire amount of work done, and the introduction of mechanical means for reducing labor costs in this way, has just begun.

For the handling of grain, the "elevator" with its weighing and storage bins of one type or another, which discharge by gravity to railroad cars or ships, has been worked out in its present form, for many years and there have been few improvements except in construction details and in making the structures fire-proof. For the handling of the grain under such conditions, belt elevators and belt conveyors are used almost wholly and the machinery equipment is the smallest part of the cost of the entire installation, the real investment being in the buildings.

For handling coal the devices used are of endless variety. Leaving the discussion of the handling of the coal at mines which forms a study by itself, we will begin where the coal comes to us loaded in railroad cars. There are many types of railroad cars designed for the handling of coal; some of them are fitted with very efficient devices for unloading into a pit below the track on which the car stands, but the greater number of the bottom dis-

charge cars give very unsatisfactory service, and are a great source of annoyance to the man who has to supply coal for large power houses, or to unload it for coaling locomotives at some large round house.

At the Fisk St. power house, which is probably the best equipped of any of the modern central stations in this part of the world, five underground hoppers long enough to take the discharge throughout the full length of the coal car have been arranged to discharge to pivoted overlapping lip bucket conveyors. At this station a force of 17 men is constantly at work discharging one car, or at most, two cars at a time, to these conveyors. This force is employed notwithstanding the fact that the Company operating this plant has a contract with the coal supply house to give them the coal in dump bottom cars. The engineers in charge stated that at least one in three of the hopper-bottom cars have become defective in some way, by the time they arrive at the power house, so that they do not figure on getting more than two-thirds of their coal through the bottom of the cars under any circumstances, and the ordinary practice of the men is to shovel the coal over the sides of the cars without paying any attention to the dumping devices. Of these there are some two or three makes of cars which have proven satisfactory, but of which no large number are available. If the conveying machinery manufacturer could count upon efficient cars of this character there would be no occasion for unloading devices, but fully 95 per cent of the coal unloaded from railroad cars is taken out by hand at a cost of from 5 cents to 7½ cents per ton; this is for merely getting the coal over the side of the car. To meet this difficulty a number of unloading devices have been designed. In the ship-loading plants at Cleveland, Ohio, a revolving cage is provided in which the car is held rigidly while the cage turns over bodily, upsetting the car and dumping its entire contents into a hopper below. This equipment is unquestionably cheaper to operate, *per ton,* than any other device yet put on the market, but the first cost of the installation is so great that it cannot be thought of except where enormous capacity is demanded. For ordinary purposes it is necessary to use either an elevator of the type shown in Fig. 9 or else one of the grab bucket equipments which will be described later.

An elevator device is installed at the coal washery of the Wilson Coal Washing Co., Carterville, Ill., which has unloaded as much as 200 tons per hour from gondola cars with four men operating it; three men in the car and one man operating the driving machinery. This gives a capacity of possibly 1600 tons of coal per day at a cost not to exceed $10.00, allowing about $2.00 per day for the power for operating the machinery. Such a saving as this over hand labor is very noticeable, but it can be said that this equipment cannot unload coal in which there are any lumps larger than 3 in. to 4 in. in diameter, and for this reason the equipment cannot be used where mine-run or lump coal will have to be taken, even occasion-

ally, unless the occasional shipments are unloaded by hand. The equipment is lower in price than almost any other satisfactory device for unloading cars and it is so built that there is but little wear and tear on the machinery, so that maintenance does not form a considerable part of the expense of operating this equipment.

For handling coal where it has been discharged from the railroad car to a hopper from which it can flow by gravity, an endless number of devices have been provided. In many cases the belt conveyor, which has been taken as the simplest form, still lends itself

Fig 9.

to the problem as especially desirable. A belt will handle very large quantities of coal noiselessly without any attention whatever except the setting of the discharge tripper and the occasional oiling of the moving parts and can be put in at as little expense as any other device adapted for carrying coal on a level and in a straight line. The belt, however, does not have the flexibility of the chain conveyor and can seldom be made as compact and in handling very large lumps of coal the chain conveyor can be depended on for better service than a belt would give, as the large lumps may make the belt run out of line and chafe at the edges.

Belt conveyors for this work must be provided with a rubber cushion added to the ordinary friction surface furnished on ordinary rubber belts and the belt itself must be of the highest class if it is to give satisfactory service. The conveyor is supported ordinarily on the carrying side by idlers spaced from 3 to 5 feet apart, each set of idlers consisting of three or more pulleys, one under the center of the belt and two under the edges, set at a sufficient angle to form the belt into a trough to hold the material. A mistake has been made by many manufacturers of belt conveyors in setting these troughing rollers at too great an angle. If the rollers are set at an inclination from 20 to 30 degrees, the inclination given the belt is enough to make it carry all of the coal possible, and the bending of the belt is not so severe as to cause a deterioration of the fabric of the belt itself. The steep rollers cause the belt to crack lengthwise along the line where the bending ocurs and in this way causes a very rapid deterioration. Formerly it was the practice to form a single roller to a smaller diameter in the middle than at the ends, to shape the belt into a trough for this work, but the result of a belt running over this form of roller, is that the edges do not travel as rapidly as the edges of the pulley on which it is running, and the center part of the belt is running much more rapidly than the smaller roller on which it rests. The same difficulty is met where a conical or hemispherical roller is introduced under the edge of the belt and a loose pulley provided to carry the middle. The presence of the loose pulley was a great advance over the beveled cone device, as it allowed the middle portion of the belt to travel at the same speed as the roller on which it runs but the edges of the belt always had some sliding action on some part of the conical or hemispherical support against which it rested, causing a rapid wear of the edges of the belt. It was these two difficulties which led to the introduction of the three-roller belt-troughing idler now generally used.

Construction details of the three roller type idlers and the inclination at which it lifts the belt are the principle points which the Engineer has to consider at present. The lubrication of these rollers must be accomplished in such a way that gritty dust is not introduced into the journals. For light work it is far better to use some form of continuous oiling mechanism than to use a hard grease. The fact that the latter construction automatically pro-

tects the bearings against the dust above referred to is often a sufficient consideration to justify its use. It stands to reason, however, that the hard grease lubrication will cause a larger amount of power to be consumed than would be the case where a thin oil is used and the journals properly protected by mechanical means. There are three or four manufacturers who have worked out these details with much refinement and the life of the belt conveyors installed by them is the best argument in favor of paying an advanced price for their product.

Where belt conveyors cannot be used for any reason, there is frequently a choice between a chain and a steel cable. Where the amount of coal to be carried is comparatively small or where the length of the conveyor is great, a steel cable lends itself particularly to consideration.

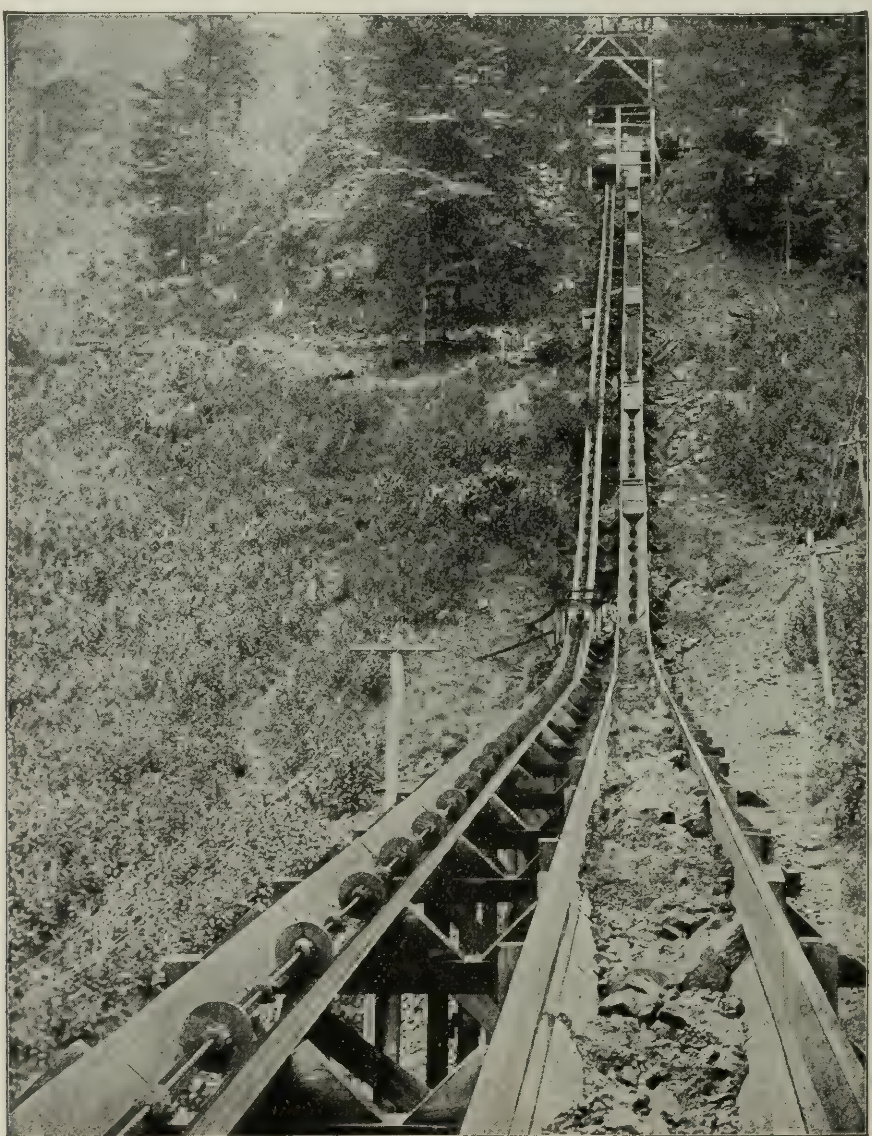


**Fig. 10.**

There have been constructed several cable conveyors over 1000 ft. long and Figs. 10 and 11 show one of these taking coal from

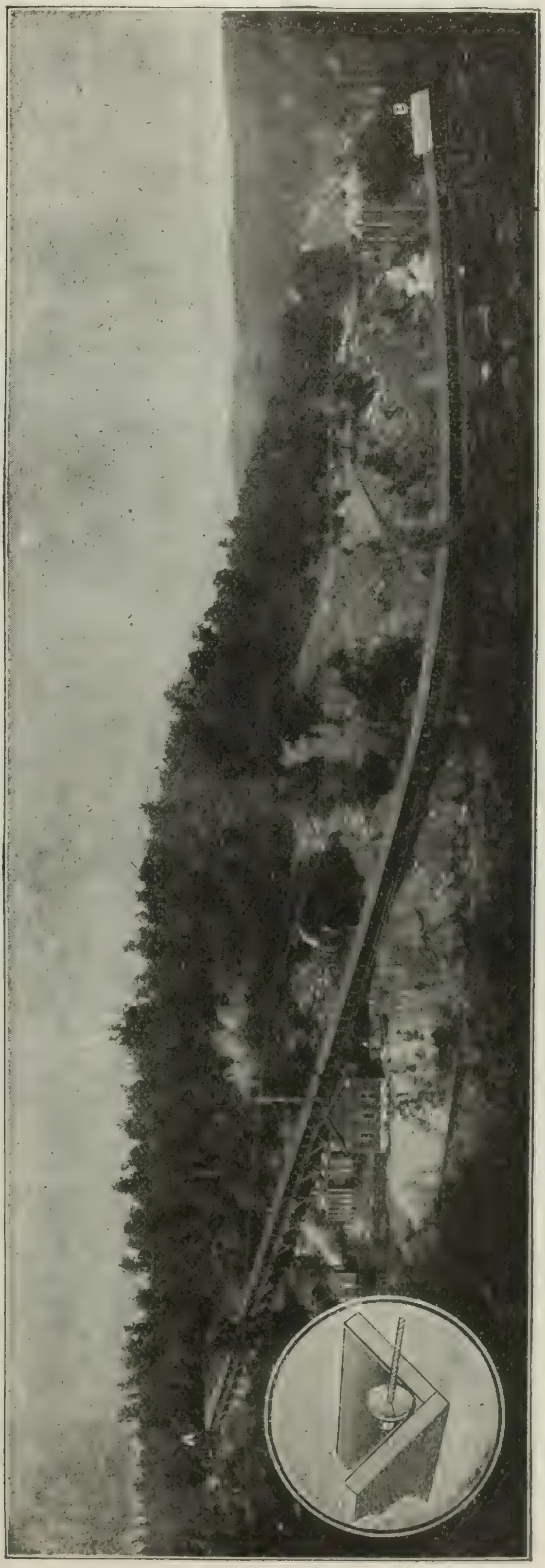


Fig. 11.

a mine tipple and delivering it something over 1100 feet away to the screening plant where it is loaded into railroad cars. These conveyors can be run over curves vertically or horizontally and require less frame work than any other type of conveying machinery. The equipment here shown handles something over 200 tons per hour and could handle considerably larger quantities if the material

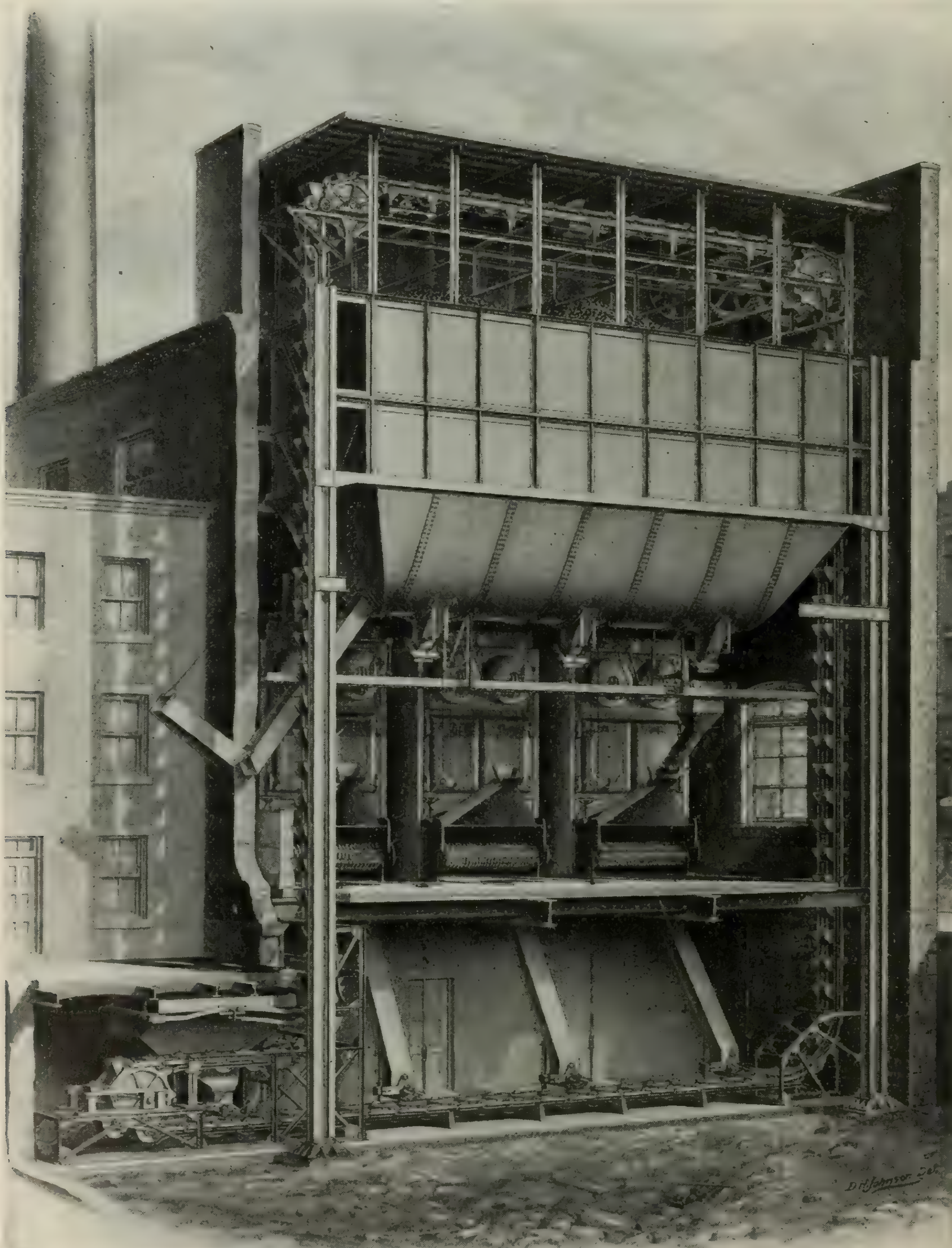


Fig. 12.

was fed to it with any degree of regularity. The possibility of making these conveyors work satisfactorily depends primarily upon two things—a cable which will not stretch and which will not untwist in service and a sprocket wheel over which the cable can be run even when it has stretched slightly.

The first difficulty is met by making the steel cable of strands, half of them twisted in one direction and half in the opposite direction. These strands when twisted together in the cable cannot be unstranded without lifting one set of strands out of the cable formed by the strands of the opposite lay. This permits us to set the carrying disks at fixed distances and maintains them in these positions even after long service. In a number of instances the same cable has been used on these conveyors for six or eight years, and so far as the writer knows, they are still in perfectly good condition. The cable, no matter how carefully made, will stretch slightly after the pitch blocks or carrying disks are put in place and with an ordinary rigid sprocket wheel, a very small amount of stretch will throw the cable entirely out of pitch with the sprocket wheel on which it was originally intended to run. This is automatically overcome by a special wheel having a hinged tooth which opens out automatically to a larger pitch circle and adapts itself to any variation in the pitch of the blocks as they come to the sprocket wheel in the travel of the cable. This arrangement avoids resetting the coal carrying disks and also greatly simplifies the splicing of the cables.

Where very large quantities of coal are carried over moderate distances or where very large lumps of coal have to be discharged at intervals we are still compelled to use chain devices, but for heavy work the steel bar link chains of long pitch fitted with the self oiling rollers which have been described, are by far the best device which has yet been brought out.

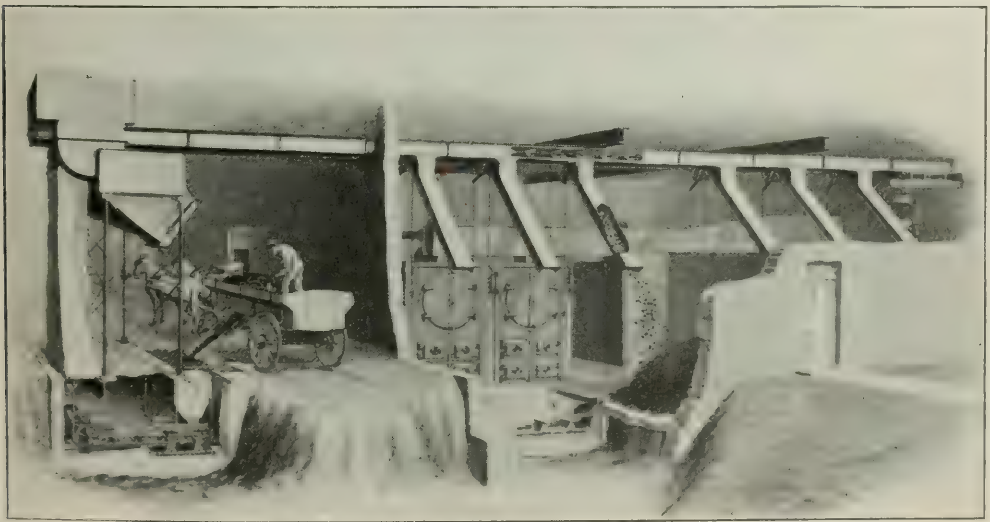


Fig. 13.

These steel chains lend themselves to the formation of various types of elevators, of which the one shown in Fig. 12 is frequently used. This is the standard pivoted overlapping lip-bucket conveyor which is composed of buckets 24 in. long hanging by gravity at the articulation of the chains and maintaining a vertical position throughout the circuit of the conveyor. The buckets are arranged with lips at the ends, which overlap on the horizontal parts of the conveyor and prevent the spillage of coal between the buckets in loading. The buckets are tilted by a projection on the bucket at the lower part, which dumps it over the point where it is desired to discharge the coal. The details of construction have been carefully worked out by a number of manufacturers, four of

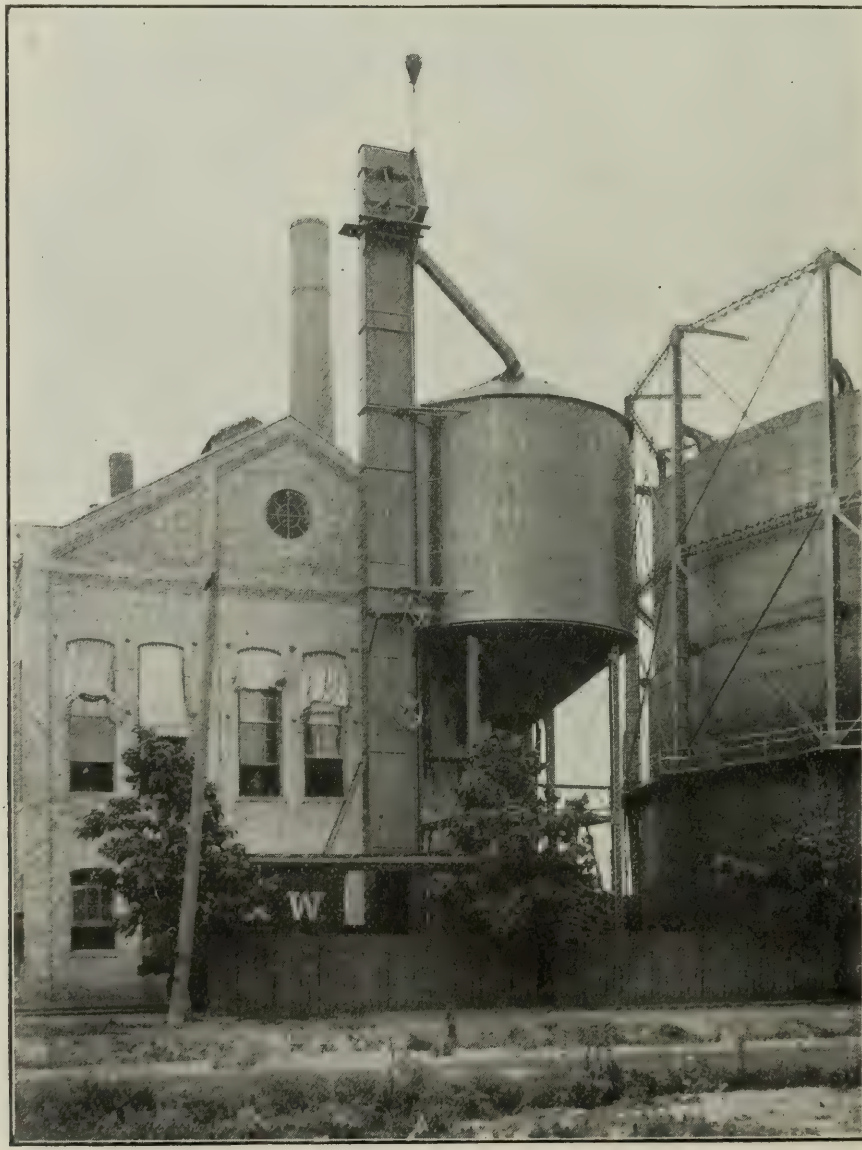


Fig. 14.

whom have very successful equipments which do not infringe each other's patent rights. All other manufacturers of this class of machinery, so far as the writer knows, are infringing the patent rights of one or more of the four referred to.

The conveyor shown in the cut was installed at the Cleveland Arcade Building, Cleveland, Ohio. The conveyor handles about 30 tons of coal per hour and is adapted to the weighing of coal when received; and also when discharged to the stokers, by means of a traveling weigh-hopper which receives the coal from the storage bins under the conveyor and delivers it to the individual stokers as required. These conveyors can be adapted to handle any amount of coal from 30 tons per hour upward and are the most economical device yet brought out for ordinary power house work.

For power plants which would not require so large a capacity as 30 tons per hour there has been brought out a somewhat cheaper type of equipment which has proven itself quite efficient except for the amount of coal carried. This consists of a V-shaped bucket

Fig. 15.

carried at intervals between steel bar-link roller-chains, the buckets provided with projections which allow the chains to be entirely covered along the lower horizontal part of the conveyor; the cover serving to prevent ashes falling on the chains and injuring the articulations and rollers. The buckets for this work are made of cast iron to avoid corrosion by the acid in the ashes. To avoid rapid wear of the trough way along the lower horizontal part of the conveyor, cast iron plates made of a hard iron mixture, are used as a lining for the trough. These will last a number of years for this service and the whole equipment can be installed at considerably less cost than the pivoted overlapping lip-bucket conveyor. This conveyor is shown in Fig. 13.

Frequently power houses have been built with roofs so low that it is impossible to store coal satisfactorily in front of the boilers at a high enough level to have a gravity flow to the stokers. Fig. 14 shows a storage tank which can be placed outdoors and filled by a vertical self-sustaining elevator shown in the illustration, the coal being drawn from the storage into a second conveyor which will distribute automatically to the stokers and return any surplus back to storage; otherwise two ton wheeled buggies can be filled from the storage tank and run into the boiler room, to be dumped into smaller hoppers immediately over the stokers. The installation shown in the view is a coke storage equipment of the Northwestern Gas Light and Coke Co. at Cicero, Ill. Here the coke is drawn into

Fig. 16.

buggies as stated above, and is discharged into the water-gas machines, on the second floor of the building standing immediately behind the storage tank.

For locomotive coaling stations a large variety of plants have been built of varying efficiency.

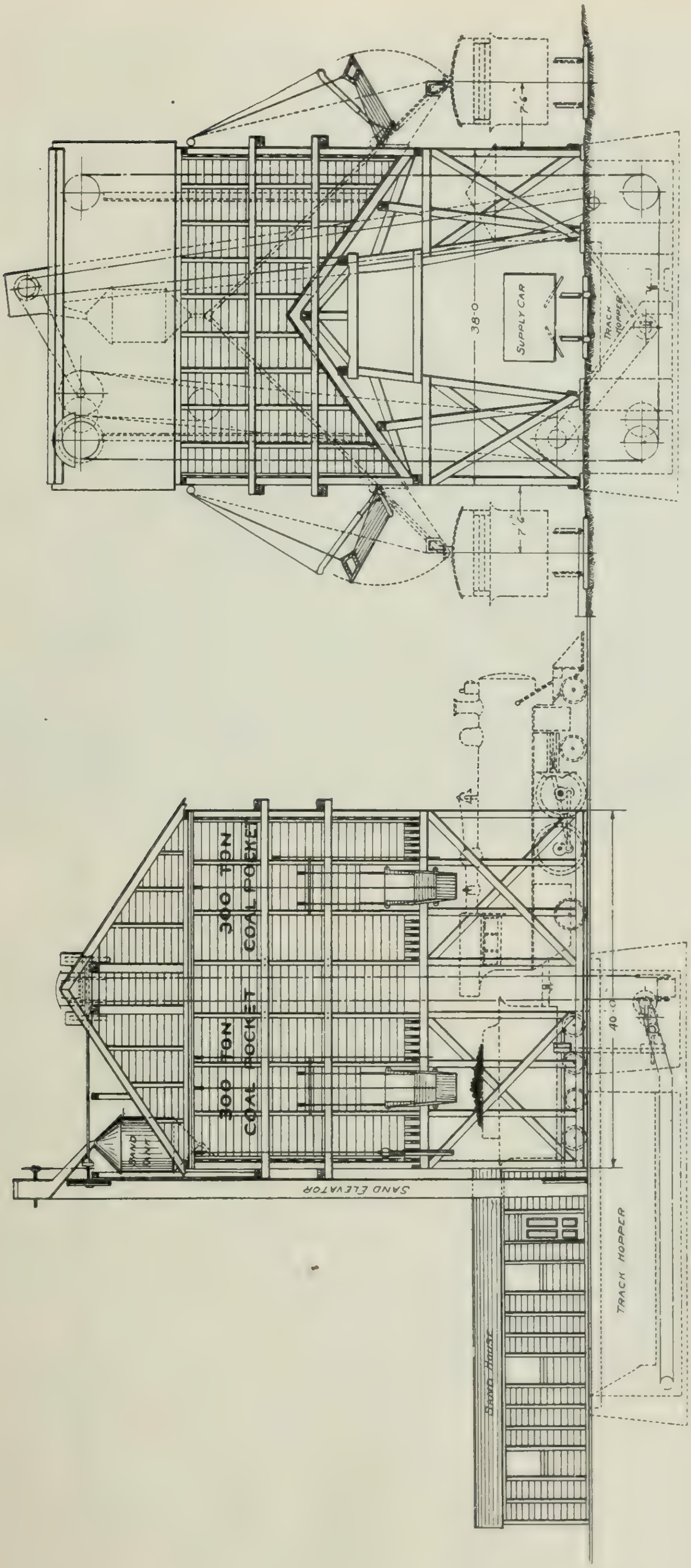
A station shown in Fig. 15 is located at Columbus, Ohio, on the Big Four R. R. The mechanical equipment was furnished by the Jeffrey Mfg. Co. and is of somewhat different type than the later stations built by that Company; the elevator mechanism being considerably lighter than more modern practice.

Fig. 17.

A station built last year for the C., R. I. & P. Ry. at their 47th street round house in Chicago is shown in Fig. 16. This is provided with a belt conveyor 30 in. wide, driven at the lower end by a 25 H. P. gasolene engine. The coal is discharged from hopper-bottom cars into a steel hopper entirely below the track and when it is necessary to shovel coal from gondola cars as shown, the wooden guards shown in the view deflect the coal throughout the entire length of the car into the same track hopper. Fig. 17 shows the coaling chutes for this equipment which are fitted with an undercut gate with ample space above the gate for lump coal to pass the gate without choking. The end of the chute is provided with a vertical stop plate preventing the coal following entirely over a low tender and yet allowing the chute to be set high enough to clear the highest engines. Fig. 18 shows a large double track station fitted with an outside steel sand-tank, drying house for sand, and a sand elevator, outside the coal storage bin. This equipment is arranged to provide storage for two kinds of coal and to have both kinds accessible from the two coaling tracks. A long underground hopper is provided to allow the discharge of coal from the entire length of the Otis drop-bottom car at one setting. The storage capacity is 600 tons. Fig. 19 shows a very cheap type of a station, fitted with a vertical elevator adapted for handling 15 tons of mine-run coal per hour; all of the coal to be shoveled from gondola cars and the coaling to be done on one track only. The station can be placed on scales if desired and can be adapted to discharge coal on the receiving track where it is desirable. Without these two features, this station can be built at a cost of $3,000, which is believed to be the lowest price for efficient machinery and proper construction which has ever been attained.

As we stated before, fully 90 per cent of the coal unloaded from railroad cars in this section of the country has to be unloaded by hand shoveling from ordinary gondola cars; a large amount of this, particularly in the case of locomotive coaling stations, must be mine-run coal.

It is impossible to unload this with the elevator type unloader, and to meet the demand for a machine which would unload mine-run or lump coal and would take out all of the coal contained in the car without shoveling, the Jeffrey Mfg. Co. has designed the bucket shown in Fig. 20. This is carried by a traveling crane, and being supported by four cables it always stands squarely in line with the crane, which permits the operator to drop it with great exactness very close to the sides of the car. This bucket has very great power and will unload any kind of lump coal and will practically clean up a car without the coal being touched by hand. Some 300 or 400 lbs. of coal has to be pulled out of the corners of the car with a shovel in cleaning up, but the bucket takes out every particle of this when it is drawn a few inches away from the sides.



300 TON
COAL POCKET
300 TON
COAL POCKET
SAND ELEVATOR
TRACK HOPPER
SUPPLY CAR
38-0
40-0


Fig, 18.

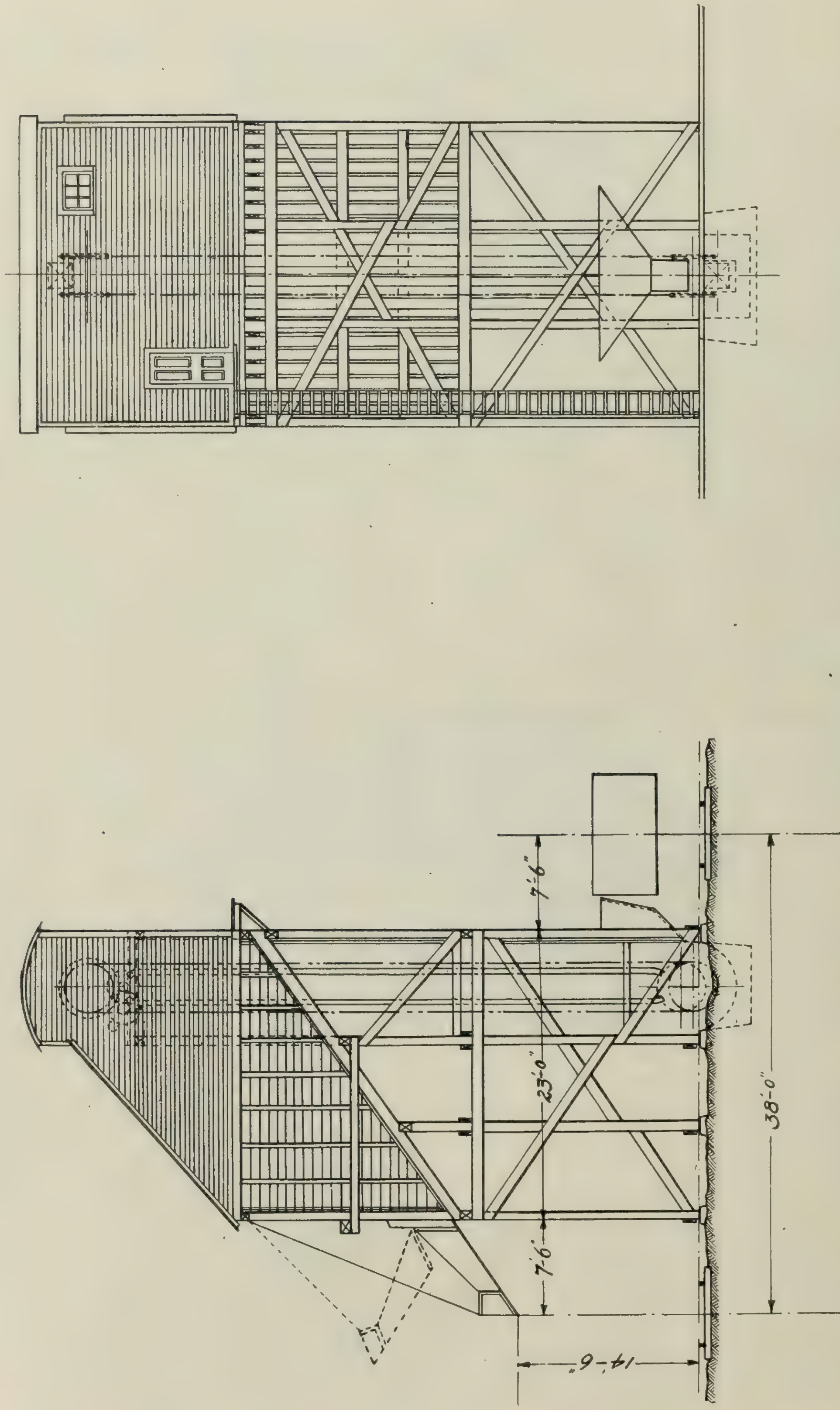



Fig. 19

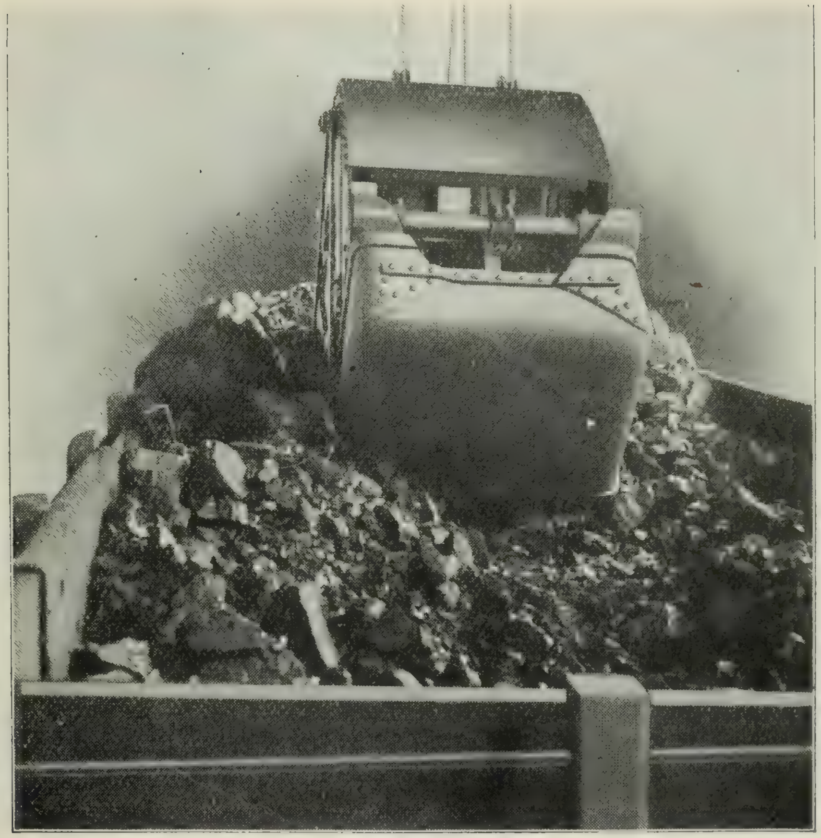


Fig. 20.

This apparatus has not yet been actually installed for coaling locomotives, but has been installed in a number of power houses and storage plants similar to the one in Fig. 21, which shows the power house of the Scioto Valley Traction Co., a short distance from Columbus, Ohio, where 3,000 tons ground storage is provided outside the building and between this and the building a railroad track passes from which the coal can be unloaded and either transferred to the ground storage or into the building; a receiving hopper with the crusher beneath it is mounted on a traveler inside the building, which arrangement permits the coal to be crushed over any of the coal storage bunkers. The plant in question is a slow moving equipment with 48 cu. ft. capacity grab bucket, and is capable of unloading from 60 to 75 tons of coal per hour.

The adaption of this equipment to railway work is shown in Fig. 22, where a crane is mounted to travel lengthwise of the car shown, and adapted to deliver the coal into the pocket illustrated. This stores 250 tons of mine-run coal which is accessible on the two tracks. The Scioto Valley plant has demonstrated a cost of something less than 1 cent per ton for unloading coal and transferring the same into the coal bunkers. The plant in question should equal this performance, which is better than anything that has been actually

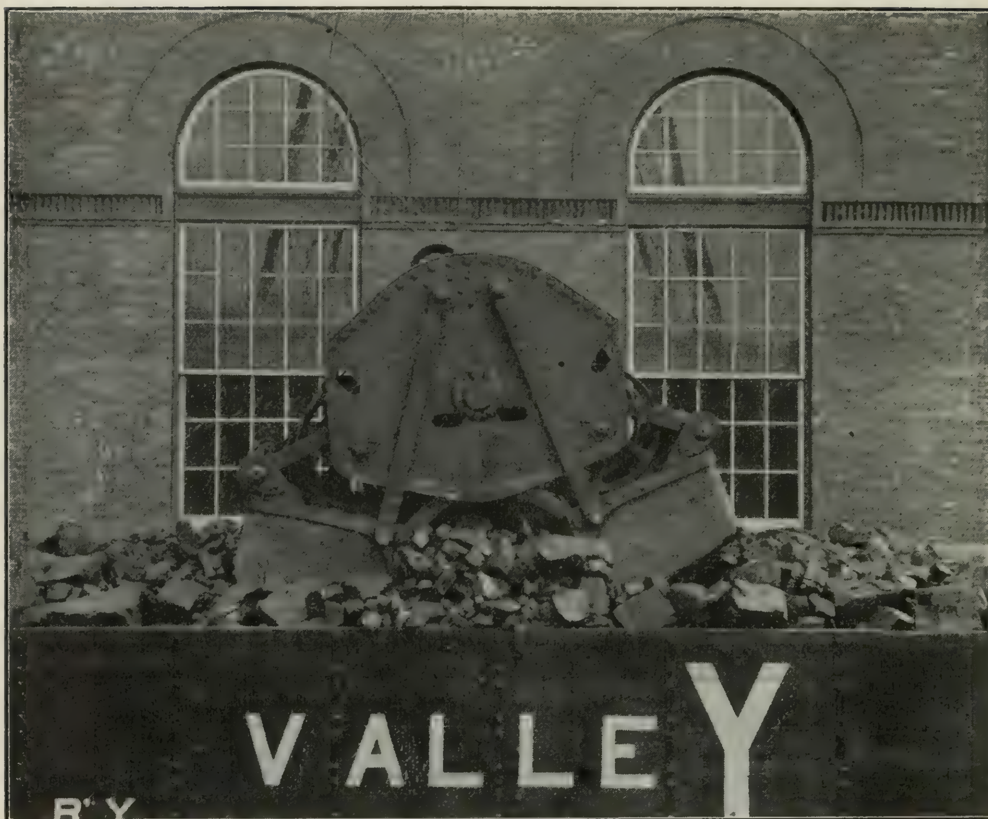



Fig. 20a

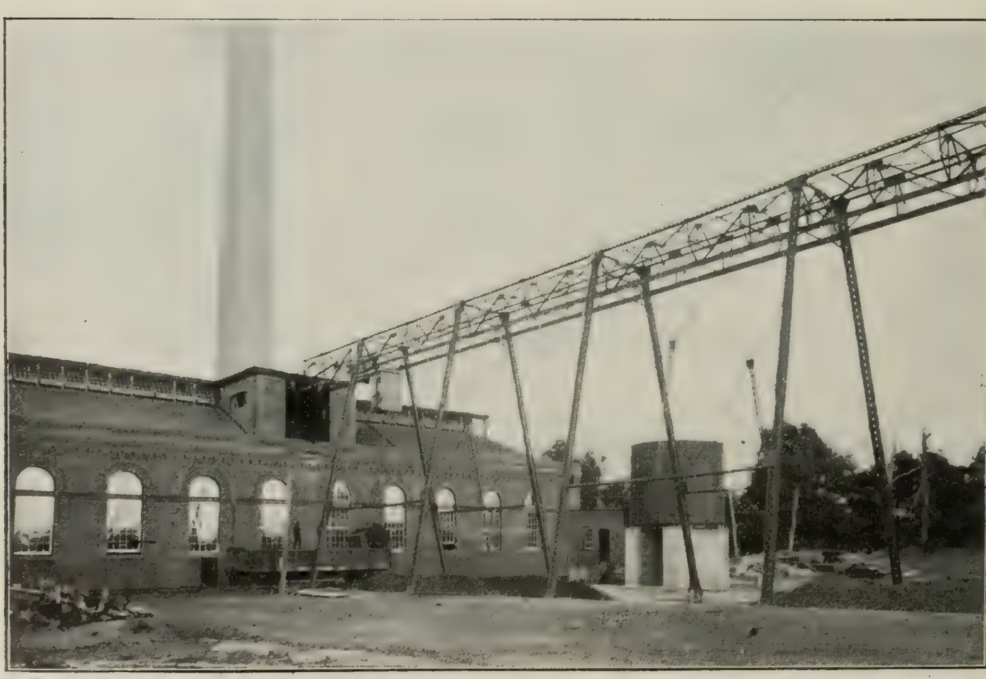


Fig. 21.

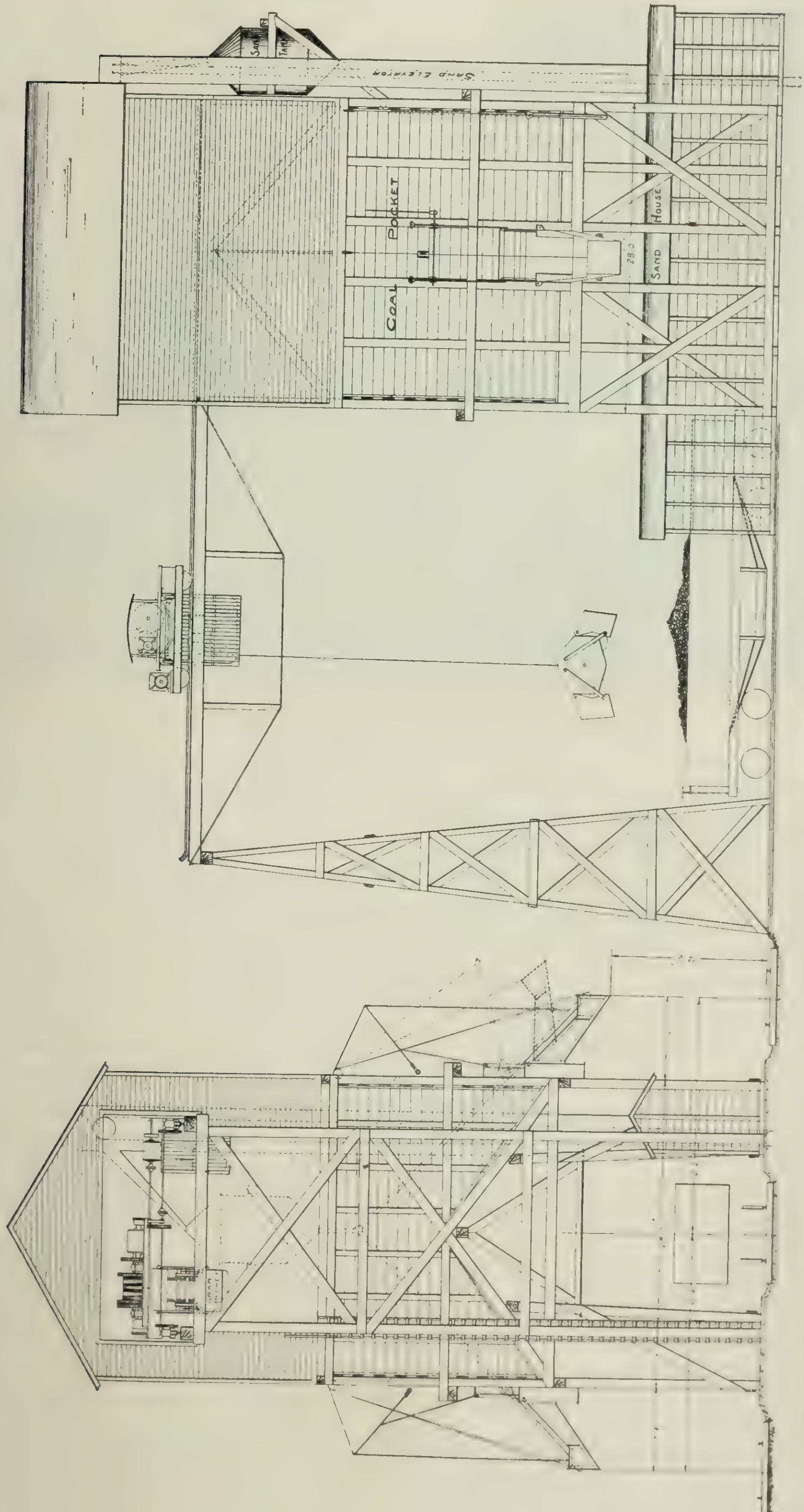



Fig. 22.

Fig. 23.

demonstrated in unloading into a standard elevator-type pocket, even where the coal all came to the station in hopper-bottom cars.

The type of station shown is very flexible and can be adapted to remove ashes from a pit underneath the coal receiving track and also to take coal out of the same pit when it is received in hopper-bottom cars. The cost of this station is approximately the same as the elevator type, but it lends itself more readily to fire proof construction, and we hope shortly to have a station of this character installed, which is altogether fire proof, and which should become the standard of construction for locomotive coaling equipments in the future. A station of this type can be equipped with a scale pocket without any difficulty whatever, and the one in the illustration includes a sanding equipment with storage for 200 cu. ft. of dry sand and 50 yds. of raw sand, with drying apparatus inclosed in the same shed.

The mechanical equipment for coaling stations has been modified to a certain extent for the handling of ice at a number of places for Armour & Co. and Swift & Co. One of these is shown in Fig. 23. Here the ice is discharged into a breaker and comes down a flexible chute as illustrated. The breaker and hopper above the same are mounted on a traveler so that the ice can be distributed over a number of cars without keeping a switch engine on the track to move them.

In concluding this paper on conveying machinery the writer would like to take this opportunity to say something on the ethics of

engineering of this character. Conveying machinery is a specialty and it is almost impossible to supply a conveyor machine equipment of the highest possible efficiency when the details are closely specified by the purchasers' engineers, or by disinterested consulting engineers, unless the latter are themselves specialists in this class of machinery. The manufacturers are always willing to give full information on the dimensions, capacity and general character of the equipment manufactured by them to any persons contemplating the installation of such machinery, and engineers should not feel under any obligation to a manufacturer when they find it necessary or advisable to ask for this information.

We are frequently called upon to make estimates and rough drawings of machinery adaptable to special purposes and we do not feel that our customer is under any obligation to us for this information beyond keeping the same confidential and we are entirely willing to furnish expensive designs and carefully estimated costs to anyone who seriously contemplates making the installation in question; all we ask is that these designs be not submitted for general competition.

It is only fair that every manufacturer should go to the same expense in preparing plans and estimates, and if one design is far superior to another, the manufacturer providing the same should have the benefit of his engineering skill, and his design should not be submitted for general competition.

This principle is not adhered to by a number of consulting engineers and this results in much ill feeling on the part of a firm making the design which is frequently used by one of his competitors when submitted for general competition. In other words, what the manufacturer expects is to have a "square deal" and to meet honest competition, where every man has to furnish his own designs.

## DISCUSSION.

*Mr. W. L. Abbott*—(M. W. S. E., chairman.)—Our friends the Civil Engineers (of which profession I do not happen to be one), formerly, and I presume yet, claim that all engineering, except military engineering, is civil engineering, and that they do that kind of engineering. Gradually, by differentiation and subdivision, other branches of engineering have been established and recognized, and this subdivision has been carried on to mechanical, electrical, hydraulic, etc., and still others, until the different kinds of engineering which we hear of now-a-days are almost without number. In these subdivisions, however, there are many kinds of engineering, the titles of which are legitimate, and their followers are justly entitled to the special names. As one of these kinds, I think we can mention that of "Engineers of conveying apparatus." It is certainly a branch by itself, and one who is not intimately connected with it does not realize the great detail to which it has been worked out. On this account I think we are all very much instructed by this paper.

*Mr. C. Kemble Baldwin*—(M. W. S. E.)—I have just a few questions that I would like to ask, in connection with the belt conveyor part of the subject. Mr. Joor speaks of canvas belts being, in most cases, better adapted to general conveying than rubber belts, but he omitted to mention one of the worst features of the canvas belts: that is, that they are not waterproof and that they are very much affected by atmospheric changes. I know of a case where, as a result of stretching and subsequent contraction due to sunshine on the belt, followed by a light rain, the whole "take-up" end of the conveyor was pulled down.

*Mr. Joor*—I beg to correct Mr. Baldwin in his statement. I was discussing the application of cotton belts for the handling of packages, more particularly in stores and warehouses—of the department store class—and I stated that when the belt was to be used for handling rough materials it was necessary to use the best class of rubber belts with the cushions. Mr. Baldwin represents the Robins Conveying Belt Co., and what he says is true. I agree with him that when it comes to handling rough materials out of doors, the cotton belt would not be suitable.

*Mr. Baldwin*—One other point I would like to bring up. Mr. Joor spoke of the limit in length of the belt conveyor being 500 ft. The 500 ft. conveyor is a short one now. I had the pleasure of building a conveyor about three years ago which was 1000 ft. from center to center of end pulleys, and which elevated material 65 ft. It was a 36-inch belt and handled 500 cubic yds. of material an hour. The material was city refuse, consisting of ashes, boxes, barrels, and such refuse. This conveyor had a tripper which carried a 60-in. belt at right angles to the main belt running at 1000 ft. a minute.

*Mr. Joor*—I was talking more particularly about warehouse work, as 500 ft. is not by any means the limit.

*Mr. Baldwin*—You speak of the angle of the idlers destroying the belt and causing cracking in the center. I think that is a mistaken idea, because I know of a belt in operation for eight years, where the *inclined pulleys were on 42 degrees,* which we realize is very bad practice, because it made the belt hard to train. I know of only three cases of the belt splitting in the middle, not because the belt was not properly supported, but because the rubber was of a poor quality, allowing the belt to crack. The friction being poor, the belt itself disintegrated. This belt was 20 in. wide.

*Mr. Warder*—What amount of that width was turned up at the sides?

*Mr. Baldwin*—The center pulley had a 7 in. width of face.

*Mr. Warder*—Then about one-third of the width, each side, was used.

*Mr. Johnson*—(Link-Belt Machinery Co.)—Mr. Joor referred to the noise of the elevators in the postoffice and said it was due to the long pitch chain. This, I think, is true, but I think it was unnecessary to use a long pitch chain on account of the expense of bucket

attachments, as the buckets could have been attached to a chain of short pitch by the same means as now employed.

The noise is also due to the pulsating motion in the chain, caused by the sprocket wheels being driven at a uniform speed. I believe if an equalizing gear or other means for eliminating this pulsating motion had been used, the noise would have been a great deal less. I have not seen the machinery myself, but understand that all gearing used is rough cast iron, except the first pair from the motor. This, in my opinion is very bad practice, as all gears for machinery in public places should be made noiseless as far as possible. If the specification, as it was written by the U. S. government engineers had been followed more closely, the machinery would have been more suitable, as I believe they specified 6 in. pitch chain and even if this pitch was too short, a 9 in. or 12 in. pitch chain would have been superior to the 24 in.

I take this opportunity to remind engineers that the location and use should govern the design of "Elevating and Conveying Machinery." An elevator built for a coal mine or similar place, is usually not suitable in an office building, while a machine having all the refinement for eliminating noise, would be out of place in a boiler shop, and I question its manufacturers, for the sake of a small saving in cost, are justified in installing machinery that is known to be noisy, in places where employes are engaged in clerical work and noise would be nothing but objectionable.

*Mr. Geo. M. Brill*—(M. W. S. E.)—I might mention one instance where we were able to do better than anything Mr. Joor has mentioned.

We are designing a power plant of some 3500 H. P., where the location is such that we are able to gravitate coal from pockets, filled from drop-bottom cars, directly to automatic stokers and from which the ashes drop into hoppers discharging into railway cars. This is accomplished without any excessive expense for railway connections, the location being such that, within a horizontal distance of 200 feet there is a vertical distance of about 100 feet between two railway lines. So that, by gravity alone we are able to handle both the coal and ashes.

*Mr. W. A. Shaw*—(M. W. S. E.)—I occupy a position where I am supposed to be an expert from superintending the laying of water pipe, to designing a power house. In city work, it is necessary to prepare plans and specifications in detail for the various improvements, machinery, etc., that the city intends to make to improve its water supply. When it comes to the coal conveying machinery, we go eventually to see our friends, such as the Jeffrey Mfg. Co. and others that are experts in this line of work. At each power plant the conditions are peculiar to itself and as most of the improvements consist in remodeling old power plants, it is necessary to fit the conditions to the particular plant being considered. Finally at the City Engineer's office some scheme is decided upon, viz., belt conveyor, bucket conveyor, or perhaps grab bucket. Plans and

specifications are prepared which are sent to the different manufacturers asking them to submit details with their estimates to conform to the general plans.

*Mr Baldwin*—The conveyor man is frequently not given an opportunity to work to the best advantage, for when a consulting engineer designs a power house, he will often plan everything else before he considers the conveying machinery, and then, when a power house is about half completed, attention is turned to the coal handling machinery. In three instances that I recall, the structures were prepared for a certain type of conveyor, and then it was decided to put in another type. and new holes had to be cut in the walls, etc. It seems that they take up the scheme for the conveying machinery the very last thing.

*Mr. Abbott*—I would say that such power houses were designed by an architect. I have known architects to design and build buildings, and then have to cut a hole in the wall afterward to put in the boilers.

*Mr. P. Junkersfeld*—(M. W. S. E.)—I came here to listen to what might be said, rather than to take part, particularly because we are so fortunate as to have here tonight a number of people who are specialists along this line, and whom the Chairman has aptly termed "conveying machinery engineers."

There are several types of conveyors not touched on tonight—at least not to any great extent. I refer to the gravity bucket conveyors. In the design of these various conveyors, mistakes have been made, but I think they are being rectified rapidly. I have in mind the scheme of driving which is under going a change. Now that the change is under way, it seems strange that no one had thought of it before. Conveying machinery is essentially not complicated, but it is surprising how many fundamental engineering principles are often overlooked.

*Mr F. S. Hickok*—I have been particularly interested in that portion of the paper relating to the unloading of coal from cars. This has not been touched upon in the discussion, and I would be glad to say something on this general subject.

I agree with Mr. Joor that there are two good practical ways of doing this—with the continuous bucket elevator, and also with the grab bucket. The cost of unloading coal from cars is, of course, dependent upon the kind of coal and the conveniences for unloading. Mr. Joor's statement of 5c to 7½c per ton for unloading by hand seems reasonable. I have known of cases where the cost was as low as 3c, and other cases as high as 10c per ton, where unloaded by contract. There is evidently, therefore, a good chance for economy in power-station design in the unloading of coal from cars.

The grab bucket offers a means of doing this work very economically. Not only can it be used to take the coal from the cars and drop it over the sides, but arrangements can be made for taking it directly from the car and depositing it in bunkers over the boilers.

One way, as suggested by Mr. Joor, was to have a two rail elec-

tric traveling hoist, operating on a straight overhead track and depositing the coal in a fixed hopper. I believe a more flexible arrangement would be a traveling electric hoist operating on a single rail track. With this, you can go around curves with as short a radius as 15 ft., also over switches if necessary. It gives, by far, the most flexible system for working out this particular problem.

There are, of course, a number of different ways of handling this general problem. Some of these are—the double-rail traveling hoist, as Mr. Joor has mentioned and a combination of this hoist with a traveling crane bridge; also the single-rail traveling hoist, to be used on both fixed track and moving bridge, making the combination still more flexible. For the storage of coal in yards, the Gantry type crane is probably most suitable. It can be proportioned to the particular duty required, and makes a very efficient way of coal handling.

*Mr. Baldwin*—Mr. Joor has said very little about the question of capacity—one of the distinct features of the different types of conveyors. Chains have a limited capacity. It may be interesting to know that 750, 800 and even 1,000 tons or more of coal per hour can be handled with a single belt, and it is being done every day.

*Mr. Johnson*—The Link-Belt Machinery Company has furnished for a ship loading plant at Seattle, Washington, a chain conveyor of about 315 feet centers which has handled 1,100 tons per hour. It may not be practical to build conveyors of this type as long as 1,000 ft. centers except in special cases, but in regards to capacity, I think it is unlimited.

*Mr. Abbott*—Regarding the handling of ashes by the coal conveyor, I believe that, sooner or later the conveyor people will come to realize that this is a mistake, and to be avoided where it is conveniently possible.

Mr. Joor stated that coal itself acts as a lubricant to the axles and links of the coal conveyor. Cinders contain grit which cuts them out rapidly. The great difficulty experienced in coal and ash-handling apparatus is the cutting out of the bearings where the ashes come in contact with long link conveyors; bucket conveyors are often arranged so as to receive the ashes from one side, and to have the ashes get in to the bearings on one side more than on the other will have the effect of stretching out that side; by stretching I mean they will elongate through wear, and it is frequently necessary to interchange the links between the long and short side to equalize the strain. If plants were designed so that some other means would be provided for handling the ashes, there would be less than half the trouble now experienced in the continual renewals of worn-out parts of the present bucket conveyors. From my experience I know that this is a very troublesome and always present source of expense.

I think our friends who manufacture devices for unloading coal from cars are a little prone to over-estimate the saving to be made by the use of their devices. The Commonwealth Electric Company

has been able to unload cars of coal at an expense of between 3c and 4c per ton by hand.

We have received propositions from people to furnish apparatus for doing that work, upon which apparatus the depreciation and maintenance would amount to considerably more than the cost of doing the work by hand. One part of coal elevating apparatus is some device for picking it up from the car or from a storage yard, and placing it upon the conveyor, and the Gantry crane has been suggested for this. It is a very good device for taking coal out of the storage yard, but we must recollect that coal in a storage yard is put there usually for emergency purposes, and while there may be a great amount of coal in the yard all the time, very little goes in and out at one time, and such an expensive device is not always warranted. We have found that a locomotive crane upon a truck, which will run on a standard guage, is a very efficient and inexpensive apparatus. Such a device can handle, when well managed, a ton of coal a minute, and that, when working 24 hours a day, would mean 1,500 tons of coal per day.

There is also another device for picking up coal and loading it into cars, which I believe is used at the steel mills for loading ore. It consists of an incliined conveyor on a truck, supported so that one end is on the ground and the other end at an angle at sufficient elevation to deliver the material into the car. The conveyor upon this inclined platform—driven by a motor or steam power—scrapes the material up and carries it directly into the car which is to be loaded. These devices, while less expensive than the overhead bridges and conveyors with the grab bucket, are probably as efficient for emergency work which would be the duty of the loading device in a coal storage yard.

As for the dump bottom cars, many that have been built are not a success, and many of these cars have been remodeled, the trap being removed and a solid bottom put in.

There are other types of dump cars now in use. I refer particularly to the side dumping car and to the large hopper cars which the railroad companies use, and I think these will become more common in the future, as there is cetrainly a great demand for them.

The unloading of lump coal in the ordinary coal yard costs 10c to 15c per ton. This, in a yard where they are handling thousands of cars a year, would be enough to pay, in a short time, for a sufficient number of cars to keep that concern supplied with coal. The objection to them (particularly the hopper car) is that they cannot be used for any business which is not provided with a receiving hopper below the track.

*Mr. E. E. R. Tratman*—(M. W. S. E)—The paper illustrates very clearly the great flexibility of the conveyor system in its adaptability to a wide range of materials and operating conditions. There is apparently a good field for its application in railway freight houses and on steamship piers to reduce the enormous amount of trucking but at present comparatively little has been done in this

line. Experiments have been made with conveyors laid along the pier or dock, and delivering to an inclined conveyor which discharges the packages upon the deck. This continuous movement should be more rapid and efficient than the intermittent movement with trucks and derricks. Two forms of conveyors not included in the paper may be mentioned. The first is a continuous pan or trough conveyor used in some cases instead of a series of separate buckets. This is formed by sections of troughs having bottom and sides but no ends, the sections overlapping to form a continuous trough. Such a conveyor is used in carrying the red hot coke raked from the retorts of a gas-works plant. The second has a runway formed by a series of wooden rollers journaled in the side frames; this is set at an incline and packages run down by gravity. The grab bucket is rather outside the scope of the paper, as it belongs to the intermittent class of conveyor which includes also the overhead cable tramway, the telferage system and the cable haulage system.

## CLOSURE.

*Mr. Joor*—The most important point brought out was in reference to handling ashes in the same conveyor with coal. We all recognize the fact that ashes is the worst material we have to handle. We have built some conveyors for corundum and have had no trouble with the chains used in them; they are protected so that the corundum does not get into the journals. If the manufacturer of the pivoted over-lapping bucket so generally in use today, had taken any such care and provision for protecting his chains or providing a lubricating device in his rollers which would run clean oil from the center of the chain journals out to the sides, the difficulty with the ash conveyor would not have been noticed to so great a degree. The principal difficulty with this particular machine is that the make of conveyor, most generally in use today, has a most abominable chain in connection with it. I believe we are unfortunate enough not to have a representative from that firm here tonight, but they certainly do put up a magnificent piece of work with the exception of the chain. The engineer, to lubricate the chain, has to put oil on the outside, which carries dust into the journals, with the result that the chains are bound to wear out, just as Mr. Abbott has said. But if the chains were protected with hardened steel bushings, that difficulty would not materialize.

The difficulty we meet in handling ashes is the corrosion of the conveying mechanism, due to the presence of sulphur in the coal; this action is largely overcome with the malleable iron construction. There has been a little controversy as to whether chains should be of malleable iron instead of steel with the choice somewhat in favor of steel. But it is comparatively easy to protect the chains from the ash dust, and if a carefully made malleable equipment is provided with this protection it is good. If the chains are made up with the care spoken of, there would be no difficulty from stretching. The

trouble is that when other companies come in competition with the builder of the cheap chain, the fact that so many of these cheap chains are in service enables our competitor to get the job.

In regard to grab-buckets and clam-shell buckets, one point has not been brought out; this is the difference between the grab and the clam-shell. The clam-shell usually consists of two parts which are a close approximation to a quarter of a circle closed around the centre and forming a semi-circular receptacle when closed.

This type of bucket raises itself off the material to be dug, and for this reason has not the power of the grab-type, which consists of two parts, flatter than the halves of the clam-shell as ordinarily made; and these two parts in the open position are separated by a very considerable distance. The closure of the bucket at first consists of drawing these two parts together in a direction very close to horizontal. This accumulates the material within the bucket and allows the bucket to be filled when the closure takes place, by the last movement of the closing mechanism.

The clam-shell-type of bucket on account of its rotary movement can unload but about 70 per cent of ordinary coal from an open car. The rest of the coal has to be handled preliminarily by a shovel and made up into heaps over which the clam-shell can close. The grab-type of bucket can close against the largest lumps of coal which with a clam-shell-type of bucket, would have to be broken by hand for the bucket. Further than this the grab will remove approximately 95 per cent of the coal without shoveling and the 5 per cent is drawn away from the side of the car to a point where the bucket reaches it, after which the bucket will entirely clean up the bottom of the car, avoiding the necessity of piling the coal for the bucket to close over it.

The points brought out by Mr. Johnson and Mr. Baldwin are merely detail differences in lines of manufacture. Mr. Baldwin has had some experience with belts with high pitch rollers quite contrary to the results we have obtained in our own work. We had to replace some belts several years ago where we used a high pitch roller, in spite of using the best belts we could obtain, and the Jeffrey Century belt is quite as good as any other on the market, and is so regarded by the trade.

Mr. Hickok brought out the point in regard to having a single rail track in connection with grab bucket. The suggestion is a very good one indeed, but the capacity must be limited on account of the limit of weight which can be handled on a single rail track, without making it enormously heavy.

In the matter of power house design, which was mentioned by Mr. Baldwin, the principal thing that the designing engineer should look out for is a high roof. Plenty of room should be allowed behind the boilers so that the conveyor man can take care of the coal handling apparatus.

Mr. Shaw is certainly entitled to all the information we can give

him. We have already given some information to the city and will be glad to give more.

I want to bring out one point not mentioned before. That is, the chain conveying devices ought to move at a very slow rate of speed, and in the ash conveyors for the city work, a very high speed has always been specified. This has always been insisted upon by one of our competitors, and has resulted in the giving of a construction which will not last nearly as long as a slow-moving elevator would have done. A slow-moving elevator is entirely impossible in public work, when a high speed equipment is specified, for the reason that the lowest bidder is practically assured of the contract unless there is a real defect in his device. The slow movement makes it cost more, but not excessively more. The points brought out in regard to the Post Office construction are not of any great importance, and are largely trade details which do not go very far.

Mr. Baldwin's suggestion as to the capacity of the belt conveyors was just touched on in my paper. The difference in the belt conveyor and chain device is in speed. The chain must move slowly, and 100 or 150 ft. per min. should be the limit. If material is properly delivered to a belt so the material does not have to slide on it, a belt conveyor could be run at 1,000 ft. per minute without any mechanical difficulty. The wear on a belt is of course increased by the higher speed, but in ordinary practice it will run a number of times faster than any chain device could be run. A chain is sometimes run at 300 ft., but if we can keep the speed down to 80 or 100 ft. for regular bucket work, it will be well. In gravity bucket work the speed can not be over 50 ft. per min., because the introduction of gravity action makes this impossible.

## STANDARDIZATION OF METHODS AND APPLIANCES IN TELEPHONY.

Frank R. McBerty, M. W. S. E.

*Read before the Electrical Section, December 15, 1905.*

It is the work of the Engineer to build a machine accurately fitted for a service. Ordinarily the requirements of cheap construction and proper operation are antitheses; a rough proportion is found to exist between quality of performance and labor of construction and operation. He must determine an adjustment between the quality and the cost of performance. To build a cheap machine that will not work is easy; to build a costly one that will work well is not difficult; to build a cheap one to work well is his sufficient task. The Engineer then must provide a standard of performance, or a variety of standards to meet a variety of conditions. In telephony the standards must cover transmission, and promptness and accuracy of switching, since these are the particulars on which the salable quality of the product of the machine depends.

Although a rough standard of telephone transmission was established fairly early in the history of the industry, it is only recently that a rational use of such a standard has been made. With the advent of long distance lines, transmission equal to the conventional standard was found entirely inadequate for an increasing percentage of connections. To meet the new conditions, a new instrument was designed and a new standard was established, namely, the transmission from a solid back trasmitter provided with two cells of Fuller battery in an aerial line of No. 8 wire, 200 miles long. In the lack of adequate data the assumption was made that all subscribers' lines would require the maintenance of such a standard transmission, and all equipments were judged in relation to the standard, with no great regard to local conditions. Doubtless in many cases the maintenance of the high standard required for connections of extreme length was not warranted by the occurrence or frequency of such connections in the locality and was needlessly costly. Studies of the percentages of conversations which are held over circuits having different resistances or losses up to the limits, which are now available, together with more accurate knowledge of the costs of maintaining different grades of transmission, now permit the determination of the quality of transmission which is adequate and suitably economical for any locality.

Ordinarily the transmission is affected by the nature of the telephone and transmitter, the resistance and insulation of the conductor, and the nature of bridges and repeating coils necessarily present in the circuit for other purposes. In determining the desirable grade of transmission, the transmitters and receivers, and the

appliances in the circuit which may produce losses of energy, ordinarily can be left out of account, since good judgment in selecting and arranging appliances is more effective in reducing the cost, without impairing the efficiency of service, than any efforts at cheapening these appliances would be. In general the cross section of the conductor is the controlling consideration in determining the economical grade of transmission. Increased cross section improves transmission in a diminished proportion but it increases cost of conductor, insulation and supporting or containing structures largely. For this reason the Engineer should determine for each locality, in view of the electrical losses which will be encountered in varying proportions of the probable connections, the minimum grade of transmission permissible in view of the cost of conductors. The acceptance of a single standard applied uniformly to all cases would not seem to be in the direction of adequate planning.

To take examples; a town exchange remote from a city probably will be the center of a net-work of toll lines extending for some distance into the country. Only a small percentage of the local calls will enter the toll lines, and an extremely small percentage of those will reach such a distance as to tax the transmitting efficiency of the local system. Such a case would seem to call for a sacrifice of quality of transmission, to a considerable extent in favor of economy of construction. In the case of a large city, a considerable percentage of the conversations will be over long and profitable toll connections, while a great proportion will be through long cables. In such a case, manifestly a different standard of transmission must be established, dependent upon totally different relations between necessary grade of service and cost of giving it.

The standard of transmission should, therefore, provide a sliding scale, variable within wide limits and adjustable to actual conditions.

Only recently has a definite effort been made to establish standards of performance in switching connections. Data is now available, showing the relations between cost of operating and various degrees of promptness in answering calls, and various degrees of accuracy in establishing connections. Improved service in these particulars involves increased expense in switchboards, central office space, operators' wages and trunk equipment. The cost of the three factors last named should weigh heavily in establishing the grade of service to be maintained in a given locality. Unfortunately, the determination is complicated by the fact that in those places where cost of real estate, trunk equipment and wages are highest, the demands for service of high grade are most imperative, but nevertheless, an adjustment should be reached in each case between the cost and the quality of the switching service. The Engineer fails to exercise his function when he accepts unreservedly, standards of performance which are established under unknown conditions in other places.

In the title of this paper I have referred to "standard appliances,"

in deference to current usage. Telephonic appliances are not "standardized" in the sense of being adapted or associated with standards of performance. Proposals to standardize appliances now being generally agitated, are rather to reduce telephonic appliances to a few types for uniform application.

The important considerations tending toward so-called standardizing of appliances are, reduced cost of manufacture, reduced quantity of stocks, increased promptness of supply and universal knowledge of uses and maintenances. These considerations are to be weighed against several important disadvantages to which I shall refer later.

The most energetic promoter of standardizing appliances ordinarily, is the manufacturer, whose interest it is to reduce costs by increasing the quantity of his uniform product. Frequently, however, the reduction of cost effected by standardizing, fails to manifest itself in reduced price to the consumer. In such a case the standardizing of appliances falls short of the possible advantages. It is a matter of common experience that the making of a few special appliances is very costly; the making of a moderate number may approach the minimum possible cost; toward the minimum no great advance will be made with further increase of quantity of uniform product. This consideration indicates that special and unusual appliances in small numbers should be avoided whenever possible, excepting for definite experiments, or important special uses; that a variety of standard appliances used in considerable numbers may be preserved; and that a single type of appliance should be adopted for universal use only when upon careful study it is determined that an adequate grade of service can be attained by its use in nearly all cases.

In these times of extraordinary rapid development in the telephone business, promptness of supply from stock or manufacturer is an important consideration. Such promptness of supply can be attained only if the variety of appliances be strictly limited. The consideration may be a temporary one, however, and its weight often can be reduced by fore-knowledge and planning.

The advantages arising from familiarity with telephonic appliances appear both in relation to the public users and to the operating forces of the company. The public is strikingly incompetent in the operation of mechanism. Mere unfamiliarity with the telephone greatly retarded the spread of its use; the same cause operates against it with respect to any change, even a trifling one, which affects the mode of using it. The addition of a button to push during ringing, the substitution of an automatic for a magneto call, the requirement that a subscriber give his order twice instead of once, or give his order in a particular sequence, involve long and patient education; the education of all users is never accomplished and the system labors under a continual burden of inaccuracy and frequent neglect to employ it when it would be successfully used, if it were familiar. We have no measure of the benefits in increased

business and accuracy of service which would arise from uniform apparatus, but no doubt exists that substantial departures from uniformity are seriously harmful. It is to be noted that this consideration affects mainly outward appearances and modes of handling appliances, not their details of structure.

The efficiency of the operating companies' employes is largely dependent upon their familiarity with the structures. I refer not so much to the operators as to the construction, inspection and maintenance forces. The existence in a single exchange of a variety of appliances for the same general purposes very greatly increases the burden of educating these forces for their work; and during the process, which is never completed, faults in the structure are continually produced or permitted because of unfamiliarity with the less common appliances. It is a familiar fact, that a lack of uniformity in the sections of the multiple board, by hampering the shifting about of the operators, may seriously impair the efficiency of the force. In constructing or maintaining the plant, mere differences in the arrangement of terminals and colors of wire insulations result in defects in performance which are costly to locate and eliminate. So simple a deviation from common practice as requiring that the telephones be poled in the circuit has resulted in serious deficiencies of transmission in a large number of instruments. In ordinary mechanism lack of interchangeability of parts resuts in the obvious failure of the parts to fit in place. In the telephone industry the misfits usually are not apparent; they are left to work their insidious evils unobserved.

The disadvantages of standardizing appliances are somewhat more general in their nature than the advantages. Possibly the most important of these is that standardizing prevents the natural selections which operate where a variety of forms are present to bring the fittest to the fore. Purchasing agents and telephone engineers do not proceed like the forces of nature in their selection of the best types; their knowledge of facts is always inadequate, their compromises are not always wise, and their selections are not adjusted continually to changing conditions. Possibly the most striking example just now of the insufficiency of the Engineer's best efforts at foresight, is found in the unexpected and enormous spread of telephones, which compels the early abandonment of exchange equipments planned for long lives. Other examples are the persistent refusals, first on the part of the Bell Companies and later on the part of the Independent Companies, to adopt party lines. Even the provision of a central battery in the exchange, now accepted as the obvious and only rational construction, was strongly opposed by competent engineers. The distrust of automatic mechanism and the opinion which appears to be current that automatic trunking and automatic distribution of calls are unprofitable, may in time prove to be unfounded.

The only substitute for natural selection of the best, from types naturally competing, is an exhaustive study and unprejudiced

judgment of all structures which promise improvement or economy in any direction. Such research can be conducted only with great resources, and even then it calls for rare foresight and persistence. From these considerations it might seem that standardizing of appliances was safe and even necessary for an operating company with an established business, but undesirable for a new comer compelled to make his way on a showing of good reason for his existence.

A related disadvantage of standardizing appliances appears in the inertia of ideas and of plant, which result from limiting the types of appliances. The public, familiar with the use of only one form of instrument, may decline to use a different though better one; construction and maintenance forces familiar with one form will oppose, malign or even destroy strange appliances. It is a truism in telephony that the opinion of an operator cannot be accepted as to the deficiencies of familiar apparatus or the advantage of new apparatus.

The conservatisms of the public and of operatives can be overcome by education, however; the most serious inertia is that of the capitalist. Where a variety of appliances are used it is not difficult to show economies of one over the other; the results of their competing performances are manifest; and when the competing appliances are rivals it becomes a matter of life and death on the part of the owner of the less efficient to find a better machine. If only one type of appliance is under observation, the basis for adequate study is lacking; the advantages of improved apparatus are not apparent; decrease of profit is not so directly traceable to the need for an improved mechanism, and the motive for prompt replacement is lacking. Even though it be possible to show a theoretical saving in annual charge in favor of improved appliances, there will be no haste to make the change.

In determining upon standard appliances much, and often undue, weight is given to the prevailing usage. Such usage sometimes will be found justified by the fact that the appliance is the survivor of many; but not rarely its wide use rests only upon conservatism or inertia. In examining the reason for existence of such a usage, a study of its origin often will be enlightening. The conditions which produced it may be found to have disappeared or diminished in importance; or, as in a number of cases which might be named, mere thoughtlessness may have been responsible for its extensive use. An interesting example is the tubular drop, designed as a bridged clearing-out drop, but used almost universally as a line drop cut-off during conversation. The costly construction was necessary for its limited use in the permanent bridge of the circuit; but it was needless in the more common use as a line drop. Similarly the bridging magneto was designed for multi-station lines; but its use became almost universal for lines where its costly winding of fine wire was unnecessary. Even now the sales of bridging bells are mainly of the costly sort adapted for extremely severe con-

ditions of service, which only a small percentage of them are required to meet.

In so far as it is possible the selection of standard appliances should be based upon costs rather than prices. Prices of new and highly efficient or patented appliances are likely to have no fixed relation to costs. Thus, the adjustment of quality, to costs of performance, may be entirely vitiated by unexpected and arbitrary changes in price.

While it is desirable that telephone systems in their present condition of partial development should be left reasonably free to improvement, the Engineer should be on his guard against waiting for new developments. The structure produced today will develop faults tomorrow of a sort peculiar to itself. Existing and tried structures, perhaps with some trifling improvements, the effects of which are certain, should ordinarily be preferred to promising new ones.

One point remains to speak of, which is an important and not always tolerable factor affecting the uniformity of method and appliances in the telephone industry. This is personal interest. On the part of the manufacturer it appears in reluctance to modify his product, or to abandon an obsolete type. On the part of the Engineer it often appears in his adherence to appliances of his own design. The inventor is notoriously a poor judge of his inventions. It is nearly always possible to make an appliance different and in the absence of adequate data to advance claims of improvement. The best example of telephone engineering practice in existence, which is also an example of the closest adherence to standard methods and appliances, has been achieved almost wholly without invention on the part of the engineers who created the system. Their work has been confined to inspiring others to invent, and selecting the most desirable from the product.

## DISCUSSION.

*Mr. McMeen*— M. W. S. E., Chairman —The paper is now open for discussion, and I know that Mr. McBerty will be pleased if you will enter into the discussion freely and frankly.

*Prof. Morgan Brooks*— M. W. S. E. —This has been an exceedingly interesting paper to me. It needs a second reading, however, to get all the points, since as the Chairman has stated, it is very much condensed.

It seems undesirable to make changes in apparatus unless to produce a marked improvement. Recently in Chicago I encountered one of the pay telephones requiring a nickel in order to attract the attention of central. I see no advantage over the older style, and only an annoyance in the change of method. The Bell Company used to conceal improvements in transmitters by maintaining the same external appearance, to prevent too urgent a demand from the public for the improved apparatus, the apparatus being leased, and

not sold. When an improvement is made it should be shown by some external change.

*Mr. McMeen*—There are said to be in use by the company you mention, in the United States, some two million sub-station devices, the telephones of which are owned by the same company. We will assume that each new type instrument would cost at least $1.00, and if a new one was produced greatly superior to previous types, two million new transmitters would be demanded immediately at a cost of not less than $2,000,000. Standardization in that respect is distinctly limiting progress.

It is interesting to know that there are in use today, by the telephone company already referred to, four methods of announcing the payment of money at the sub-station. These methods must be known, remembered and operated by people who are not in the telephone business. The method most in use now, in the 5-cent type, is that which requires the deposit of the nickel before one can get the Central Office, and if the line is free it is indicated by a ticking sound. In fact, the shibboleth in common use is "No tick, no nick." At one time it was a serious question whether that method of collecting coins ever could be used, because, in case of a line in trouble, the nickel would be beyond the reach of the subscriber.

*Mr. J. P. Cracraft*—Transmission standards, as noted by Mr. McBerty, seem to me the one requiring the most consideration, but is the standard hardest to establish.

In the Bell Company, with its one main Engineering Department to dictate, this and other standards, should be more easily determined upon, though the value of former standard apparatus, already in use, to which new, made necessary by advancement in the act, must conform, retards complete standardization. As noticeable examples, the transmitter with its uninsulated frame forming one side of the circuit, and the receiver, with its exposed binding posts; the proper development of both of these pieces of apparatus essential to standard transmission are retarded by being necessarily designed to conform with valuable apparatus now in use.

In the Independent Companies, where each one to a great extent has the opportunity to select and establish its own standards, from several sources, they usually profit locally in that they generally select equipments well adapted for its local requirements—though in this field a good salesman sometimes outwits a good engineer, resulting in the installation of telephone apparatus not well adapted for universal local and long distance service.

Line construction deserves considerable consideration in establishlishing a standard transmission and as Mr. McBerty implies, this part of many plants suffer from over-standardization, or rather, the blind following of former practice.

*Mr. K. B. Miller*— M. W. S. E. —I think every man in the telephone business has had occasion to think about this general matter of standardization. The fact Mr. McBerty has pointed out, that standardization does tend to retard progress, is perhaps a suf-

ficient reason for much of the lack of standardization that has existed up to the present day, and make us wish there had not been as much standardization as there is. We must know that a company with millions of instruments of a given type in the field will not only not welcome, but perhaps may try to prevent the introduction of something different—particularly if the difference is only a slight one. In other words, a slightly better transmitter or receiver would not warrant the expense to both consumer and manufacturer of replacing and putting in the junk pile practically their complete equipment in that line.

Mr. McBerty referred to the fact that cost of apparatus and not selling price should govern largely, the choice of standards. I will cite one instance which I think illustrates that very well: Not long ago it was considered inexpedient and impractical, from a financial standpoint, to make very large multiple boards. The price of jacks was fifty cents each. Various kinds of boards were suggested for increasing the capacity of a given Central Office equipment, without the corresponding increase in the number of jacks that would be brought about by the adherence to the straight multiple plan. That whole situation was turned upside down by a mere reduction in selling price of jacks. The reduction in price of springjacks from 50 cents each to twenty-five cents changed the entire economics of the design of large Central Offices. I believe there can be no better illustration of that point than this fact.

Another point is our inability to establish a universal standard on account of our inability to see into the future. Our hind-sight is much better than our fore-sight. If we had standardized ten years ago to the extent that many people desired, the telephone business would have been very much behind what it is today. Choosing standards involves the proper assumption of conditions that you believe will exist in the future. This is the real problem. Just so far as we can see into the future and make these assumptions correctly, especially where little data is available to enable us to make correct assumptions, just so far will we be successful in standardization. Standardization must fail in some cases because of our inability to see what is coming.

All of that will apply with much more force to the past than the future. The telephone business is an art that has grown perhaps as no other art has grown. We now have enough history behind us to enable us to draw curves and plot out what we think is going to happen in the future. A few years ago even that rather poor facility was not available to us. So I believe in the future we can standardize much more wisely than we did in the past.

I feel inclined to question Mr. McBerty's statement that inventors are universally poor judges of inventions. I will not deny that this is generally considered to be a fact, but Mr. McBerty is perhaps as prolific a telephone inventor as we have in the field, and I think few will be inclined to criticise the usual soundness of his judgment as an engineer. He is a good example of an engineer

and an inventor. The successful inventor in the telephone business has not been the proverbial one—the man with the wheels—but the sane, thinking man that has solved the problems as they came to him, and if necessary, did so by making inventions.

*Mr. McMeen*—I think perhaps we would all agree with both the author and Mr. Miller in that regard. Perhaps we are too near the telephone art today, and may not agree with Mr. Miller that probably the telephone inventor is nearer the earth than some others at least. I am inclined to question Mr. Miller's statement concerning, particularly, conditions of the past, as to our ability to forecast. The curves he mentions are of chief value in determining very important answers relative to traffic, and the design resulting therefrom as directly affecting investment matters relative to long distance transmission, in the design of circuits and perhaps in a smaller degree the design of apparatus. The work we are doing today, in all cases where we actually get up to the point of determination of investment, is based on using the general types and circuits of apparatus, and the general results of data as to traffic which are in use today. I, for one, do not find myself free of conscience to signify to investors, designs involving very many new and untried things, even though they have apparently operated satisfactorily.

Is it not probable that better transmitters are just outside the door? that even more sensitive receivers will be produced? Is it not even more probable that the cost of long trunk lines will be enormously reduced? that the use of expedients for eliminating the short circuiting effect of capacity will be very much improved? So I ask you, if these things are so, how can it be said that the things we do today are very much more likely to be correct than in the past? Is it probable that we are much more likely to have our forecasts come out right for 20 years in advance than of 15 or 20 years ago? I am inclined to think that improvements will come in the future to repeal much we know. In the past, however, we lacked confidence; we have that now.

*Mr. J. L. McQuarrie*—I have enjoyed this paper of Mr. McBerty's very much, and I am sure that others present here tonight must have found it instructive and interesting.

The question of standardization, it seems to me, is one which resolves itself into balancing the advantages and economies of standardization against the advantages and economies of discarding existing apparatus, and replacing it with something that is thought to be better. It is not easy to generalize in a case of this sort; it seems to me that the only thing that can be done is to take each particular case and pass upon it as a particular case when it arises. It would seem to be reasonable to expect that the inventor should not be allowed to run riot. On the other hand it would seem to be reasonable to expect that old apparatus cannot continue to give the same service today that it did years ago, because the art is advancing. I would think that the safest plan would be to take a new look at

each problem when the occasion arises, and determine whether it is best to change or not.

*Mr. W. A. Taylor*—Mr. McBerty's statements coincide with my views almost exactly. One point I think has not been brought up, and that is the demands of the customer on the manufacturer. Very frequently these are ridiculous because of the ignorance on the part of the customer. He insists on having a certain thing because he has, perhaps, tried one instrument that worked well, and does not consider whether it would continue to work well or continue to satisfy him.

There is another thing that the manufacturer has to contend with, and that is the demand for telephones simply because they happen to be large and have a fine and imposing appearance. A three-magnet generator was first manufactured; then a four-magnet, and five-magnet, etc., and I believe a generator was made with as many as eighteen magnets. The fact of the matter is, a well constructed three-magnet generator is just as good as the largest one that is made. The customer seems inclined to buy his instrument by the pound rather than for the service to be obtained, and in spite of anything the manufacturer can say, he has to furnish that apparatus. The customer pays more and is getting no more for his money; perhaps not as much. He is putting in a large investment and getting small returns. The customer possibly may not be to blame for it. He employs incompetent help; the incompetent help says "this switchboard is not good: you had better throw it away. Such and such an article is being made now which will improve the service." The principal reason for suggesting the change is that the incompetent help will get something new that does not need much work to keep in repair. The apparatus works nicely for perhaps a year, then the cords begin to wear out, and the customer is much disappointed in that apparatus. It is impossible to give first class service with any board if not kept in repair. We cannot go to the customer and say, "you had better discharge that man and hire a more competent one, at greater expense." The customer is not an engineer and anything you can say will be of no avail. So, if the manufacturer wants to keep up to date he has got to be getting out something new; it appeals to the customer and he has to re-design his apparatus, and changes the design of his telephones because it takes the customer's eye. Of course, it is the customer who is running the smaller sized exchanges, but it has been my experience that some of the so-called engineers in a number of the largest exchanges in the United States should not perhaps, be in their position. Some time ago I had a little experience in regard to testing a transmitter. The Consulting Engineer of an Exchange wanted a transmitter sensitive enough so that he could hear the rattle of a piece of paper when held at a distance of five or six feet. We made the transmitters and installed them. The whole shipment came back to us, with the word that they were too sensitive. This

man was Consulting Engineer of a large company capitalized with millions.

These are some of the things that an engineer has to contend with that prevent standardization.

*Mr. W. E. Harkness*—There is one thing that will interfere with the standardization which has not been brought out fully, and that is, the demands of the public upon the operating companies for various classes of service. As it is, we have certain subscriber sets for certain classes of service which today fills all the needs, yet daily we find people asking for other classes of service which will require new types of apparatus to meet their needs. I do not think any of us have as yet realized the extent to which the telephone business will develop or how far it will extend. This future development is one of the principal things which will interfere with the maintaining of what we now class as standard practice and standard apparatus, and will necessitate improvements and new types of apparatus from time to time.

*Mr. McQuarrie*—The Western Electric Company has recently been making an effort to standardize sub-station apparatus, and I think they have reduced the types to something like half a dozen instruments to replace about two hundred. The only reason why the two hundred types were in existence is because each engineer of each telephone company specified a slight departure from the regular type. They were all good instruments, but all different. A little effort on the part of the manufacturer brought customers to realize that they could get cheaper instruments, and a good deal better deliveries, if they would get together and agree to use one of these half dozen types, and they all did it.

*Mr. T. Dimon*—I have had occasion, before this, to feel that after Mr. McBerty has had his say there is very little to be added to his clear, concise statement of facts. He mentioned the subject of standardization of transmission and it seems to me that is one line of standardization that can be carried further than other lines of telephone work, because the sensitiveness of the human ear certainly does not vary greatly from time to time. The ability to use the telephone by the general public does, perhaps, increase, but not enough to make the standard of transmission of today differ greatly from what we can expect to be in force several years from now. I believe a good deal is being done toward agreeing on a standard of transmission or standards of transmission, to fit particular conditions. Of course there can be more than one standard of transmission; a transmission that will be sufficient for one set of conditions might not at all meet other conditions. A standard can also be obtained for a permissible amount of interference in transmission or a permissible amount of cross-talk between circuits.

*Prof. Brooks*—One thought came to me while some of the others have been speaking, and that is,—it is quite possible that the Bell Company will develop standards in one direction and the Inde-

pendent Companies in another, in such a way that it may be almost impossible for Bell subscribers to be connected with Independent subscribers. I am inclined to think that if such a thing takes place, legislation is likely to force an open-door policy and compel the different companies to interchange business in somewhat the same way that it has compelled the different railroads to accept cars from each other. Of course it has been necessary to have a standard guage of roads. That day when different telephone companies are likely to have an interchange of business will probably come. This has already been done in some of the telephone companies abroad, and in such cases it makes little difference whether the subscriber belongs to one exchange or another.

*Prof. Wilder*—In connection with the theoretical side of the question there have been many attempts made to find the mathematical relations existing between the various physical quantities. These have not always been successful although in many cases great help has been obtained by applying theories. Probably all of us are familiar with the attempts which have been made to find an accurate mathematical expression that would serve as a guide in designing an induction coil, and yet all such coils as used in telephone work today are the result of experimentation.

As an illustration of the difficulties encountered in applying theory to practice and the danger of widely missing the mark, I might relate an amusing experience that occurred while taking a course of lectures in telephonic theory under a well known German Professor. An elaborate theory was developed in which it was shown that the vibrations of a receiver diaphragm followed certain intricate mathematical laws, involving a knowledge of the highest branches of that study. As a result of long tedious demonstrations, an expression was found showing just what dimensions would best satisfy an ideal receiver and strange to say these dimensions were in perfect accord with those used by our present manufacturers. It was shown, for instance, that the diaphragm vibrated like a drum head and this is the popular belief today. This being so, it was further shown that these vibrations were more efficiently produced when the diaphragm was of a certain thickness, although as already stated, the formula obtained was rather complicated owing to the fact that many magnetic as well as physical properties of the metal had to be included in its derivation.

In confirming the mathematical results of theory in the laboratory it has been found that a piece of soft iron several inches thick will reproduce the voice currents just as well as the ordinary diaphragm, showing that the vibrations are not at all like those of a drum head, but on the contrary, are molecular in nature. They are probably those due to the well known Page effect.

This shows that even with the simplest phenomena we are still deep at sea and that often it is discouraging to try to apply mathematics to the solutions of telephonic problems. We still have hope, however, and find many instances in which great good is done by

such application. I have in mind Mr. McBerty's remarks regarding the standardization of long distance transmission. If we could have an instrument sensitive enough to show us the exact form of the telephonic currents sent out by a transmitter, we could place such an instrument at different points along a line and study the effect of resistance, capacity and induction upon these currents. This would enable us to find out what to do in order that telephonic currents might be transmitted over a great distance without becoming distorted. Unfortunately, such an instrument has not as yet been made, although the oscillaigraph, which Mr. McMeen mentioned, will do this for larger currents, such as used in power work. The difficulty seems to be in getting a moving mass small enough to respond to the very rapid vibrations and the weak currents that are characteristic of telephone work. When such an instrument is made we will be able to make long strides towards the standardization of long distance work.

*Mr. Miller*—I think Prof. Wilder has contributed a valuable fact—particularly in relation to independent manufacturers. We have all been beset with the problem of making our receivers heavy enough to pull down the switch-hooks of other manufacturers. I now suggest that we send out receivers with diaphragms adjustable as to weight—perhaps a couple of inches thick where the case is one of extreme obstinacy.

Just one more word about this standardization problem. Who is there here that will deny that Mr. McQuarrie's six standard types are not better than they would be if they had not come down to us from some of his 200 different types? Who will deny that the independent telephones today are not far better than they would be if, in the early days of the art, we had all stuck to our very crude ideas, or had been in any way hampered by standardization? I think the answer is obvious—that standardization too early in an art will do little in the progress of the art. For the independent people I think this discussion should bring about this thought—that a closer understanding should exist between the operators of telephone exchanges, and the engineers of the manufacturers; not so much on the good fellowship plan, but by virtue of a sane discussion by broad-minded men, to see what few reasonable standards can be established and how closely they should be adhered to. The whole thing points to a closer cooperation between operators and producers.

## THE ILLINOIS STATE HIGHWAY COMMISSION

In the February, 1906, issue of the JOURNAL was printed "An Open Letter" from the above Commission addressed "To the People of the State of Illinois," in which was explained the object of the creation of the Commission, what it desired to do, their efforts toward this end, etc. It was clearly put forth that the Commission desired and is prepared to assist the local authorities with advice as to the improvement of the common roads of the state. In furtherance of this laudable object the Highway Commission has issued Bulletin No. 1, which describes "The Earth Road Drag—How to Make it and How to Use it." Two illustrations are given for the construction of this simple and inexpensive, yet very effective machine, the use of which will be of great service in improving the country roads.

This little pamphlet has been published for distribution for information of the farmers, that they may by their own efforts, without waiting for action on the part of the local road commission, do good effective work on the roads passing in front of or through their own farms.

At this time of year, through a great part of *The Prairie State,* following the winter frosts and spring thaws, the roads are deeply rutted and frequently in almost impassable condition, because of the character of the soil of the roads, with water held in the ruts. The object of the drag is to remove the high places and humps, and fill up the ruts, at the same time grading the roadway to be higher in the middle, the better to drain off the surface water and the rains of spring and summer.

The drag may be made of a log of wood about 9 feet long, say 10 to 12 inches in diameter, which is split in half, and then the two pieces are fastened together about 3 feet apart, with the flat sides of the pieces both facing the same way and in a vertical position. The alternate plan, which also is very cheap, is to use a couple of 2 inch by 10 inch or 12 inch planks, in the place of the split log. The planks are also spaced with struts to be about 3 feet apart. A light chain, like a heavy trace chain, say about 15 to 20 feet long, has the two ends fastened to the rear element of the drag passing under the separating struts at the ends, with the "bight" forward, to which the team is attached. By shifting the point of attachment of the team the length of the two sides of the Y of the chain may be altered, and thus obtain a greater or less inclination of the face of the drag to the line of travel of the team, or the axis of the road. In operation, the drag is hauled first along one side of the road and then back on the other side, with the leading end of the drag near the margin of the road. The humps and the lumps of the roadway are leveled down, and the loose earth slides along the front faces of the drag toward the center of the roadway, filling up the low places, chuckholes, and ruts in so doing, and at the same time giving a crown to the middle of the roadway. The action of the team and drag will, to a certain extent, compact this moved material, which will be further compacted by all passing teams. But this "dragging" of the dirt road should be done at frequent intervals, to keep the ruts and hollows filled up and the road graded and surfaced into a good form. In a short time the roadway will be compacted into a good form, with sufficient crowning to enable the rainfall to quickly drain off the road and let it dry out.

A light piece of flat iron, any ¼ by 3 or 4 inches wide and 4 or 5 feet long, fastened on the front face and lower edge of the drag, will make it more efficient in cutting down the humps and save some wear of the bottom edge. The cost of such a drag should not exceed a few dollars, and could be made by most farmers themselves, or by some "jack" carpenter.

With an average team it should be quite easy to drag over three to five miles of road in a day's work, only one man, the teamster, being employed. A little study, observation and experience will show the best inclination of the face of the drag to the axis of the road. There is one thing, however, to be observed, and that is, *use the drag constantly,* in the spring, in the summer, and before the freeze-up in the fall. A persistent and continuous use of the drag makes the work lighter and easier for each occasion, and the roadway will continue to improve and thus greatly lower the cost of farm teaming. W.

## INLAND NAVIGATION AND TRAFFIC LEGISLATION

An Illustration of the Opportunites and Duties of the Southern Lawyer.

Hugh R. Garden, a member of the New York bar, but a South Carolinian by birth, delivered under the above title before the South Carolina Bar Association at its annual meeting in 1905, an address, in which after adverting to his graduation at South Carolina College in 1860, and passing in rapid review the immediately following war-period, and the occurrences of the ensuing years, he goes into a delineation of the characteristics of the Southern lawyer, his opportunity, duties and responsibilities.

He paints the conservative lawyer as the "bulwark of the nation when trouble comes," and prophesies that the horizon of his opportunity and his responsibility is being rapidly extended by the extraordinary growth of the country, more particularly of its commercialism as evidenced by its municipalities, and where "gold is the *open sesame*, more gold is the badge of its distinction, and most gold is the key to the 'holy of holies.'"

In this age of great "trusts" and trust lawyers, it is refreshing to hear an old practitioner admonish his fellow lawyers, mostly his juniors in years as well as experience, that *"Trust means confidence, and that is misnamed a trust which fails to inspire it. Let the 'trust' of the lawyer be the welfare of his people, and he will have his reward in their confidence."*

The speaker shows (that which holds good of northern as well as of southern states) that one-third or more of state legislators are lawyers, and that it is their opportunity and becomes their duty to initiate practical legislation, tending to further and protect the welfare of the people in the several states within their respective boundaries against the encroachments of the railway transportation trusts in directions where the arm of the Federal Government cannot reach. Or, as he expresses it, "My proposition is that every state having navigable waters, good seaports and an extensive coast line, can protect itself without interstate commerce legislation."

Waterways belong to "the people's or public trust," railways to "the private trust," and the speaker pertinently asks why the waterways which traverse three-fourths of the vast southern territory remain practically unused, and reminds us that George Washington devised plans for a system of canals to connect Massachusetts Bay with Long Island Sound, and Chesapeake Bay with the Mississippi Valley, while the short sighted statesmen of later days allowed the Chesapeake and Ohio and the James river and Kanawha Canals to become extinct; that the connecting of the Hudson river with the Great Lakes by the Erie Canal, under the auspices of DeWitt Clinton, built up the city of New York, and made it the Metropolis of America; and that the improvements in the navigability of the Mississippi and its tributaries have within the last ten years made New Orleans the grain seaport of the continent.

Alluding to the vast tonnage upon the great lakes between Duluth and Buffalo, a stretch only 1500 miles in extent, as being "five times as great as the combined coastwise tonnage of all the Atlantic and Gulf states 4000 miles in extent," he pleads for a system of waterways there affording equally "safe, continuous inland navigation." and invites "thoughtful legislators to study the problem and demonstrate how a private transportation trust may profitably accommodate itself to the public weal."

The rule is announced that "the shortest route to prosperity" is by "the shortest line of transportation of desirable products to deep water;" and bearing in mind the foregoing remarks as to the superior advantages derivable from improved water communication still remaining unavailed of, he adds: "But the waters flow to the sea unused, and the sea comes and goes from day to day with scarcely a sail to mark its ebb and flow, while we spend the time quarreling about rates of transportation with railroads;" and draws the conclusion that as lawyers, legislators and business men, his hearers ought to apply this lesson as an opportunity to supply the needs of the people of their own state, "instead of making contributions to the prosperity of outsiders;" using their brains and the surrounding facilities to adjust the details of mechanical and financial problems so as to create a system of free and cheap transportation by water for all products which require it, thus building up their cities and giving "to the world the routes and methods which nature in her economic storehouse provided in the beginning, for the use of man."

Speaking of river and canal navigation, which in the South as in the North, fell into disuse on the coming in of railroads, we again quote, "Rivers and canals are locally the poor man's friend, for any one can make and use a canal boat, and a neighborhood can thus move its own freight." "To the French System of Canals and navigable streams is attributed the wonderful distribution of wealth among all classes. A barge freighted with grain, or a torpedo boat with engines of war, may pass at will by river and canal from Havre to Marseilles or Bordeaux or Boulogne." And we might add that the immense sums spent in the canalization of the Rhine, the Elbe and other German rivers tell the same story of fruitful results, both as to the cheaper freight rates furnished directly by them, and indirectly as regulating the rates by rail.

Mr. Garden further pursues his theme, showing that the utilization of the waterways, navigable and to be made navigable, will not only increase transportation by water, but by fostering production will add new feeders to the railways, and will, by decentralizing population, tend to cause "ten or more cities of 1,000,000 population each" to arise, rather than "one city of 10,000,000," "along the Atlantic and Gulf coasts, on deep water navigation;" and as far as the interests of his immediate auditors are concerned, will tend quicker than aught else, by widespread increase of prosperity, to settle "the race qeustion," In addition he urges "the completion of inland coast navigation and the permeation of the country by navigable waterways, for defense as well as for commerce," and argues that "the cost will be infinitesimal, compared with results, alike beneficial to every part of our land."

The address has been published in pamphlet form, accompanied by a map, showing the navigable waterways of the United States east of the Rocky Mountains; and an inspection of the latter in connection with the arguments advanced in the address certainly furnishes food for deep thought, not only to the lawyer and legislator to whom are given the framing of the legislation, but to the engineer whose technical training and resourcefulness should find a fruitful field in developing the tempting opportunities held out by the numberless streams intersecting the country in every direction, for providing public highways upon the water, to create new sources of wealth, and incidentally check and regulate the freight rates (or more correctly speaking the *irregularities* in freight rates) imposed by railway companies on the use of the *quasi* public highways upon the land.

The address of Mr. Garden, coming as it did, shortly before the opening of the Congress which is at this writing battling with the governmental regulation of railway-rates, appears very opportune and throws a valuable side-light upon one phase of the methods that may be devised to save the public from the dangers of oppressive discrimination possible, where all avenues of transportation are under control of private capital, whether corporate or individual. The pamphlet is deserving of a wider circulation than it is likely to attain in its present form.

JULIUS STERN, Assoc. M. W. S. E.

## LOGARITHMIC TABLES.

CALCULATED AND PRINTED BY MACHINERY.

There is in the Society's library a book, the peculiarity and value of which is entirely unknown to practically all of its members. Though it is printed in a foreign language, it may be used with ease or consulted by any of the members, it being a TABLE OF LOGARITHMS.

To demonstrate the above quoted "peculiarity and value" of this work, the undersigned has made a translation of the preface to it, which explains its manner of computation and make-up, etc., and which is herewith respectfully submitted for the information of the Society. The tables are arranged on the same principles as the well known "Vega's Tables."

Respectfully,

G. A. M. LILJENCRANTZ, M. W. S. E.

### THE PREFACE.

It is a well known fact to every mathametician that the usual method employed for obtaining logarithm tables does not offer sufficient guarantee against misprints. The only means of making such tables fully reliable is undoubtedly the use for their calculation of an apparatus which accomplishes both the calculation and the printing or stereotying of the procured quantities.

The proofreading, upon which the reliability almost exclusively depends, will then be reduced to a mere trifle, and becomes exceedingly easy, for the only proofreading then required is that concerning the difference between the trigonomical logarithms, for the calculation of which the machine will, as may be easily conceived, serve as a "setting machine."

This circumstance suggested to me, as much as twelve years ago, the idea of publishing logarithm tables, by aid of the calculation machine* previously invented by me.

The accomplishment of such a work, however, would have involved far greater expenditures than my personal means permitted, and my plan would probably never have been executed had not our present King, His Majesty Oscar II, then Duke of Oestgothland, taken the initiative to and supported the formation of the so called: "Wiborg's Table-Stock-Company (Wiborgska Tabell Actie Bolaget) in which the most prominent magnates of Sweden took shares.

For the liberal generosity of this Association, through which the publishing of these tables has been rendered possible, I wish to extend my warmest gratitude.

According to the plan devised by me, the machine was to print the computed quantities in lead, from which were to be made galvanoplastic reprints in copper, from which the desired tables should then be printed.

The realization of this plan was, however, found to be combined with far greater difficulties than had been anticipated. Much time was consumed in overcoming these difficulties; hence the work has not been completed until now, after years of struggles.

It is presented to the public under the conviction that the mathematician will consider the greater reliability it offers over tables produced in the usual manner, as fully compensating for the lack of ornamentation in typographical respect, that others may possess as compared with these

*See note at the end.

"machine-made" tables. A work of attractive appearance, typographically, is much easier to produce in the usual manner than by a calculation machine. The difficulties in forming perfectly straight lines by the machine printing are naturally very great. The first one is to get the figures engraved with minute exactness in the different printing wheels. This successfuly done, it may happen that at the hardening of the wheels some of these may warp more or less. The least wear, furthermore, tends to make the figures more or less uneven. A different density of the lead, or the material in which the machine is made to print, or uneven pressure causes also a crowding, which has a bad effect on the regularity of the lines. No attempt to compete, by this method of printing with that usually employed, as regards the typographical appearance, can therefore be considered.

I hope, however, that to anyone who buys the tables with the object of *using them,* the work will prove satisfactory.

Concerning the arrangements of the tables, these are in the main in accordance with those of Bremiker and Dupuis. M. Wiborg.

Stockholm, in November, 1875.

Note.—I refer those who may desire further information concerning the operation of the machine to the report "sur la machine a calculer presentee par M. Wiborg," submitted by Messrs. Mathieu, Chasles and Delaunay in "Institute de France," which report is embodied in "Comptes rendus des Seances, de l'academie des Sciences, tome LVI, Seance du Fevrier 1863."

# FUEL TESTS AT THE UNIVERSITY OF ILLINOIS.

A series of investigations of unusual interest to Illinois manufacturers and other coal operators is about to be undertaken at the State Engineering Experiment Station recently established at the University of Illinois. An extensive and somewhat elaborate series of experiments with the different Illinois coals is contemplated for the purpose of determining the most economical methods for their utilization. Tests of fuel will be made: (a) under power plant boilers; (b) in residence heating boilers; (c) in gas producers; (d) to determine their chemical composition and heating values.

The fact that Illinois is the second coal producing state in the Union, and also the fact that in the period from 1850 to the present year Illinois has advanced in rank among the manufacturing states from fifteenth to third render these investigations of peculiar importance to our industries. This phenomenal advancement has been due largely to the development of our great coal resources and transportation facilities. The interdependence between these industries therefore demands the most careful consideration of the problems relating to the consumption of our coals in order to obtain the greatest economic results.

A feature of especial significance in connection with these tests is the organization of a special conference committee. In order that these tests should be so conducted as to meet with the approval of the great manufacturing and coal interests and that they should produce results of real value cooperation was desired with the leading engineers, coal operators, railroad officials and manufacturers from whom advice and suggestions would be available. The cooperation of the State Geological Survey and the University departments of applied chemistry and mechanical engineering was already assured. Accordingly, several of the leading engineering societies of the state were invited to appoint representatives to form a conference committee to meet from time to time for the discussion of matters relating to these problems. The Station has been most fortunate in the personnel of the committee chosen for the first year, the members of which are as follows:

H. Foster Bain, Director State Geological Survey, Urbana, Ill., representing the State Geological Survey.

A. Bement, Consulting Engineer, Chicago, the Western Society of Engineers.

Edwin H. Cheney, President Fuel Engineering Co., Chicago, the Building Managers' Association of Chicago.

F. H. Clark, Gen. Supt. Motive Power Burlington Road, C. B. & Q. Ry., Chicago, the Western Railway Club.

Adolph Mueller, President H. Mueller Mfg. Co., Decatur, Ill., the Illinois Manufacturers' Association.

Carl Scholz, President Coal Valley Mining Co., Chicago, the Illinois Coal Operators' Association.

A. V. Schroeder, Gen. Supt. Electric Light & Heat Co., Springfield, Ill., the State Electric Association.

Wm. L. Abbott, Chief Operating Engineer Chicago Edison Co., Chicago, the Board of Trustees University of Illinois.

L. P. Breckenridge, Director Engineering Experiment Station, University of Illinois, Urbana, Ill.

The initial meeting of this conference committee was held at the University, Urbana, Ill., on March 14, 1906, at which time the general policy of the committee was outlined, and plans for future work discussed. It is expected that the coals tested will be donated for this purpose. The plant in which the tests are to be made will not be ready for operation until some time in May. In the meantime the details of the plan of procedure will be prepared and issued.

## ABSTRACT OF THE MINUTES OF THE SOCIETY.

*MINUTES OF REGULAR MEETING, February 7, 1906.*

A regular meeting of the Society (No. 567) was held Wednesday evening, February 7, 1906.

The meeting was called to order at 8:20, with President Arnold in the chair, and about 65 members and guests present.

The minutes of the annual meeting held January 2nd, and of the extra meeting held January 17th, were read and approved.

The Secretary reported from the Board of Directors the election into the Society of the following:

| | GRADE. |
|---|---|
| Thomas R. Batte, Jr., Longview, Texas | Junior |
| Perry Barker, Chicago | Junior |
| Wm. L. Allison, Chicago | Active |
| John F. Icke, Madison Wis., transferred from Junior to | Active |
| Leonard B. Mason, Martin's Ferry, Ohio, transferred from Junior to | Active |
| Clyde H. McClure, Maywood, Ill | Junior |
| Herbert S. Crocker, Chicago | Active |
| George S. Hill, Chicago | Active |
| Charles W. Baldridge, Belle Plaine, Ia | Active |
| Thomas M. Gardner, Urbana, Ill | Active |
| Charles B. Gilson, Chicago | Active |

Also that applications for membership had been received from:

Russell J.Borhek, Seattle, Wash.
P. D. Fitzpatrick, Paducah, Ky., transfer from Junior to ........ Active
Arnold N. Lurie, Chicago.
Walter Wagner, Berwyn, Ill.
Frank J. J. O'Byrne, Chicago.
John O. Neikirk, Chicago, transfer from Junior to ........ Active
Wm. S. Fulton, Hattiesburg, Miss.
C. Kemble, Baldwin, Chicago.
H. Freyn, Cleveland, Ohio.
Lindsley A. Murr, Greensboro, N. C.
Paul R. Chapman, Chicago.
Cornelius F. Terhune, Maryville, Mo., and Chicago, Ill.
Gilbert Townsend, Chicago.
Frank R. Judd, Chicago.
Robert S. Draper, Chicago.
H. B. MacFarland, Chicago.
Albert D. McVay, Chicago.
W. C. Bunnel, Manila, P. I., transferred from Junior to ........ Active
Paul C. Van Zant, Chicago.
Melvin S. Ralls, Chicago.

And that these have been referred to the Membership Committee for consideration in the usual manner.

The Secretary also made announcement of the officers and standing committees of the Society for the current year of 1906, as follows:

Bion J. Arnold, President;
W. L. Abbott, First Vice President;
Andrews Allen, Second Vice President;
D. C. Jackson, Third Vice President;
A. Reichmann, Treasurer;
F. H.Bainbridge, Trustee for three years;
the other two Trustees being T. W. Snow and G. M. Wisner, who have one and two years respectively to serve. Also that the last three preceding Past-Presidents, Messrs. R. Modjeski, H. W. Parkhurst, and E. C. Carter, are members of the Board of Direction.

STANDING COMMITTEES.

*Finance*—W. L. Abbott, A. Reichmann, and C. F. Loweth.

*Publication*—Andrews Allen, George M. Brill, S. G. McMeen, J. W. Alvord, E. N. Layfield, R. F. Schuchardt, L. K. Sherman.

*Library.*—F. H. Bainbridge, Geo. A. Damon, B. E. Grant.

*Membership*—Geo. M. Wisner, W. J. Cahill, and J. R. Cravath.

The Secretary read "An Open Letter to the People of Illinois by the State Highway Commission," signed by Edmund J. James and Joseph R. Fulkerson, State Highway Commissioners.

There being no further business, in the absence of Messrs. Geo. H. Bremner, James Dun, and J. W. Alvord, authors of the paper for the evening "Waterways for Culverts and Bridges" (which had been printed and sent out in advance) the Secretary presented an abstract of the paper, and then read written discussion from Messrs. L. B. Merriam and J. C. Gray. Further discussion was offered by Messrs. L. E. Cooley, E. S. Rice, J. N. Darling, C. B. Burdick, B. J. Arnold, O. P. Chamberlain, and G. H. Bremner (who came in to the meeting later in the evening).

The meeting adjourned about 10:15 p. m.

## *EXTRA MEETING, February* 21, 1906.

An extra meeting of the Society (No. 568) was held in the Society Rooms Wednesday evening, February 21st, 1906.

The meeting was called to order at 8:20 p. m. with Vice President Abbott in the Chair, and about 60 members and guests present.

The Secretary made announcement of the serious accident that had happened to Past President H. W. Parkhurst, on the morning of Tuesday, the 20th inst., he having been knocked down by a train at Windsor Park and the skull being fractured, and that he had not yet regained consciousness. The Chairman (Mr. Abbott) paid tribute to the worth of Mr. Parkhurst and the high esteem in which he is held, and suggested that an expression of condolence and sympathy from the Society would be proper. A resolution was offered by Mr Layfield that such an expression of sympathy of the Society to Mr. and Mrs. Parkhurst be prepared by the Secretary and forwarded. The motion was carried.

There being no other business, Mr. S. F. Joor, the author of the paper for the evening, on "Elevating and Conveying Machinery," was introduced. His paper had been printed to be sent out in advance, but there had not been time for many to receive and read their copies.

Mr. Joor gave a resumé of his paper, with lantern slide illustrations.

Discussion followed from Messrs. W. L. Abbott, C. Kemble Baldwin, (Robins Belt Conveyor Co.), Johnson (Link Belt Machinery Co.), Warder, Brill, Shaw. Junkersfeld, Hickok, Tratman and Joor.

The meeting adjourned about 10:30 p. m.

## *MINUTES OF REGULAR MEETING, March 7, 1906.*

A regular meeting of the Society (No. 569) was held Wednesday evening, March 7th, 1906.

The meeting was called to order at 8:20 p. m. with Vice-President Abbott in the Chair and about 40 members and guests present.

The minutes of the two meetings held in February were read and approved.

The Secretary reported from the Board of Direction the following as having been elected into membership in the Society, since the last regular meeting.

| | GRADE. |
|---|---|
| P. D. Fitzpatrick, Paducah, Ky., transferred from Junior to | Active |
| Arnold N. Lurie, Chicago | Junior |
| Walter Wagner, Chicago | Active |
| John O. Neikirk, Chicago, transferred from Junior to | Active |
| Wm. S. Fulton, Hattiesburg, Miss. | Junior |
| C. Kemble Baldwin, Chicago | Active |
| H. Freyn, Cleveland, Ohio | Active |
| Lindsley A. Murr, Greensboro, N. C. | Junior |
| Cornelius F. Terhune, Maryville, Mo. and Chicago, Ill. | Active |
| Gilbert Townsend, Chicago | Junior |
| Frank R. Judd, Chicago | Junior |
| Robert S. Draper, Chicago | Junior |
| H. B. MacFarland, Chicago | Active |
| Wm. C. Bunnel, Manila, P. I., transferred from Junior to | Active |
| Albert D. McVay, Chicago | Junior |
| Paul C. Van Zandt, Chicago | Active |
| Melvin S. Ralls, Chicago | Active |

Also that the following applications for membership had been received:

George H. Herrold, Red Wing, Minn.
George F. Maddock, Chicago.
Horace J. Petee, Chicago.
Louis J. Hotchkiss, Chicago.
Albert A. Aegerter, St. Louis, Mo.
Merton G. Hall, Centerville, Iowa.
Thomas F. Geraghty, Chicago.
Andrew J. Hemstreet, Texico, N. M.
James Lyman, Chicago.
Robinson S. Moss, Chicago.

There being no other business before the Society, Prof. E. G. Smith, M. W. S. E. of Beloit, Wis., was introduced, who addressed the Society on the "Urban Tendencies of Population as Affecting the Problems of the Engineer." There were lantern slide illustrations of the paper. Discussion followed from Messrs. McCullough, Abbott, Saner, R. S. Moss, DeWolfe, Burdick, McMeen, J. S. Robinson, and Prof. Smith.

The meeting adjourned about 10:15 p. m.

## *MINUTES OF EXTRA MEETING, March 23, 1906.*

An extra meeting of the Society (No. 571), was held in the Society Rooms, Friday evening, March 23rd, 1906.

The meeting was called to order about 8:15 p. m., with Vice-President Abbott in the Chair and about 80 members and guests present.

There was no business to bring before the Society so Mr. W. T. Curtis, M. W. S. E. was introduced, who presented his paper, "A New Method of Cal-

culating Bridge Stresses by Means of End Shears." This paper had been printed and sent out in advance, but explanation of parts of the paper was made by aid of blackboard figures. The addenda to Mr. Curtis' paper prepared by Mr. J. Gibson, M. W. S. E, the author and calculator of the "End Shear Tables," was read and explained by Mr. Gibson.

Discussion followed from Messrs. Andrews Allen, Layfield, Wells, Ferguson, (by letter) Curtis and Gibson.

The second address of the evening was from Prof. W. K. Hatt, (of Purdue) who spoke on the "Physical and Mechanical Characteristics of Structural Timber." His remarks were illustrated by a number of lantern slides.

Discussion followed from Messrs. W. L. Hall and Crawford, of Washington, Layfield, Adams, Allen, W. L. Abbott and Prof. Hatt.

The meeting adjourned about 10:50 p. m.

## ELECTRICAL SECTION.

### *EXTRA MEETING, March 16, 1906.*

An extra meeting of the Society (No. 570), being the 15th meeting of the Electrical Section, was held in the Society rooms, Friday evening, March 16th, 1906.

The meeting was called to order about 8:15 p. m., by the Chairman, S. G. McMeen, and with about 65 members and guests present.

There was no business brought before the Section, and the reading of the Minutes was dispensed with, as they had been already printed in the "Journal."

Prof. P. B. Woodworth, M. W. S. E. (Lewis Institute) was introduced, who read his paper on "Schools, Engineers and Employers."

Discussion followed from Messrs. McMeen, King, Howlett, Prof. Freeman, of Armour Institute, K. B. Miller, Raymond, Hatch and Woodworth.

The meeting adjourned about 10:45 p. m.

J. H. Warder, *Secretary.*

## BOOK REVIEWS.

MODERN MACHINE SHOP, Construction, Equipment and Management, by Oscar F. Perrigo, M. E., New York, The Norman W. Henley Publishing Company, 1906. Full cloth; 7¾ by 10½ inches; 343 pages, including index and with over 200 illustrations. Price $5.00.

In the preface the author states his aim and object in publishing the book "is to produce a work suitable for the practical and every-day use of the Architects who design, the Manufacturers who build, the Engineers who plan and equip, the Superintendents who organize and direct; and for the information of every Stockholder, Director, Officer, Accountant, Clerk, Superintendent, Foreman and Workman of the Modern Machine Shop and Manufacturing Plant of Industrial America" and divides the subject matter into three parts,—Construction, Equipment and Management.

In the first, or introductory chapter, he says: " 'the eternal fitness of things,' as well as the spirit of this progressive age, requires that in whatever we design, build, equip and arrange for the production of our portion of the vast output of the manufactures of the present day, we shall strive to make it the best of its class, and the best adapted for the special uses to which it will be put, the kind of goods or machinery to be manufactured, and the circumstances, conditions and surroundings under which we are to work."

"In a great majority of cases the manufacturing plants of this country have been the result of *growth* and *progress*, more or less rapid, of the business which they were designed to accommodate. Often they began with very meager facilities for the work in hand, with poorly designed and cheaply constructed buildings, and all the conveniences and accessories of the plainest kind. As the business enlarged, greater means were available, and necessity demanded, the buildings were gradually added to and their other facilities increased. Buildings were enlarged by increasing their height, by the addition of wings or the erection of separate buildings, often disconnected and scattered, without any apparent plan or consideration of their accessibility or usefulness."

"Thus the establishment became an aggregation of buildings of various sizes and forms, requiring much greater expense for handling stock, material and product, and an unnecessarily large expense for power by which to operate it, and the entire plant often representing in a general way the worst possible arrangement for economically producing work, or for producing first-class work at all."

Chapters (II-XIV) take up the general plan and detailed construction of a typical plant of small size, occupying space 300 feet x 400 feet and consisting of Office, Draughting Room, Pattern Shop, Foundry, Machine Shop, Power Plant, Forge and Carpenter Shops with the necessary adjuncts of Storage Yard, Store Room, Railway Tracks, etc., the general lay-out of the buildings being of such a nature that the several departments may be proportionately increased should the future growth of the business require it.

Chapters II and III have reference particularly to the General Plans and General Construction of the Buildings. (III-VI) to slow burning construction; chapter VII to one-story Machine Shop of Brick and Wood and its economical construction and operation; chapter VIII, Roofs, including Saw Tooth construction, the newest type of Shop Roof for one-story construction; Chapters (IX-XII) the Construction of Chimney, Foundations and Floors. Chapters (XII-XIII) the System of Heating, Ventilation and Lighting. Chapter XIV. Power and Transmission, the best types of Engines and Boilers, and the comparative merits of transmission by Shafts and Belts and by Electric Motors. Chapter XIV, the concluding chapter of Part I, discusses the choice of Ground for Manufacturing Plants with the object of avoiding

an excessive outlay in cost of foundations for buildings and machinery, and unnecessary fixed charges on account of taxes, water supply, etc.

In Part II, Chapter XVI discusses Machine Shop Equipment, with the proper machinery, tools and appliances for accomplishing the work contemplated, the arrangement in groups or departments so as to best subserve the purpose intended, and to manufacture the product with the least cost for handling the materials in the various stages of their progress toward the completed product, and with the most efficient arrangement for supervising the work, and still to insure the desired standard of accuracy, finish, and thoroughness of the completed output."

Chapter XVII. Planning the different departments so that there shall be no "retrograde movement or unnecessary handling, the progress of the work through the different departments being so arranged that as far as possible it may be a progressive one from the raw material to the finished product."

Chapters (XVIII-XXII) take up the equipment of the tool and store rooms, draughting room, pattern shop and pattern storage room, iron foundry and forge shop.

Chapter XXIII deals with the Shop Transportation Equipment consisting of shop tracks, cars, cranes, trolleys, etc., and Chapter XXIV with the miscellaneous equipment of the manufacturing plant with reference to the smaller departments, such as Carpenter Shop, Storehouse and Paint Shop, with the Toilet facilities and the necessary foundations for machinery.

In the initial chapter of Part III, Machine Shop Management, the author states the proposition "that we shall have reached the perfect system of management when we shall have devised methods by which we may produce the greatest amount of good work with the smallest number of employes and the least amount of friction and irritation among them," and devotes a considerable portion of the succeeding chapters to the organization of the several departments and to discussing and illustrating the various systems of blank forms, cards, filing cases, cabinets and other time saving devices necessary to best accomplish this result in these departments.

In the Chapter devoted to "The Problem of Apportioning the Fixed Charges" he arrives perhaps at a nearer solution of this vexing problem than has heretofore been presented, the principal difficulty with the systems in common use being that they are either so inaccurate as to be of little value or so unwieldly and expensive as to preclude their adoption.

The last Chapter of the book takes up the questions pertaining to the health, comfort and general welfare of the employes under the headings of the Machine Shop Mutual Aid Association, First Aid to Injured Employes, Machine Shop Reading Room and Machine Shop Dining Room.

To every one connected with manufacturing interests be he owner, stockholder or employe, this work is one of absorbing interest. It takes up and elaborates in a very complete manner every important question on which either may desire knowledge. Its completeness and vast amount of up-to-date information testify to the Authors thorough practical as well as theoretical acquaintance with his subject. H. T.

Practical Electric Railway Hand Book by Albert B. Herrick. Second edition revised and corrected. McGraw Publishing Company, New York, 1906. 6⅞ by 4½ inches, Limp Leather. 460 pages, including a copious index and many illustrations. Price $3.00 net.

The reviewer has kept this volume on his desk while working up the estimate and preparing specifications for an urban and interurban line, and has found it no exception to the general rule concerning so called pocket manuals in that it contains an immense amount of good matter, but is usually silent upon the particular points upon which a reference is sought.

The book is evidently intended more for the practical man in the operating department than for the engineer, since one looks through the index in vain for such subjects as: right of way, fence, cattle guards, soldered bonds, catenary construction, three phase transmission, high tension insulators, alum-

inum conductors, Cedarman's Standard Pole Specification, turbines, rotary converter sub-stations, electric locomotives, steel tired wheels, rolled steel wheels, conduit car wiring, underground conduit costs, telephone transmission line transpositions, etc., although upon careful page by page search a small amount of matter upon one or two of these subjects may be found notwithstanding their omission from the index.

A good many estimates of costs are given, but one is inclined to look with doubt upon the information contained in a given estimate when it is observed that it was made in 1893 or 1892, as for instance the track and paving costs on pages 158 to 166.

The General Tables, Section I, are complete and unusually well arranged. The very complete table of weights of materials on pages 11 to 18 would, however, be somewhat more convenient if specific gravities were added.

The chapter on Testing, Section II, gives a great many valuable formulae, diagrams, and cuts for the practical operating man. The electrical tests are largely those that can be made with standard voltmeters and ammeters and are therefore easily applied, and will be appreciated by the man who is looking for "trouble" as well as by the one who wishes to avoid "trouble."

Section III, which is directed to Track, is a comprehensive treatment of the subject with reference to urban practice. Standard specifications are given for rails, ties and roadbed as well as complete layouts for easements and spirals on curves and useful tables of weights, quantities and life of materials. There are also a number of pages of cost estimates of track and paving work in Denver in 1893.

Something over one hundred pages are devoted to the Power Station, Section IV, and although the treatment is necessarily brief, a great deal of valuable reference matter will be found classified under buildings, boilers, engines, generators, storage batteries and switchboards.

Section V, The Line, contains tables and formulae for determining feeders and describes the numerous forms of materials and the different constructions and methods for erecting feeders and trolleys. Cable conduits and conduit construction, bonds and bonding, conduit roads, third rail systems and electrolysis are also included and treated under this same heading.

Section VI, Car House, and Section VII, The Repair Shop, consist of only four or five pages each, and the matter is very general.

A large part of Section VIII, The Equipment, is occupied with specifications and description of the type of single truck cars which were so popular some years ago. Modern Interurban Car Construction is treated in about a half page. Two or three types of trucks are illustrated and described and the composition and forms of cast wheels are given. Under Brakes there have been collected a number of good diagrams, cuts and tables descriptive of the different forms of air, electric and friction brakes. The discussion of motor equipments includes a great deal of practical matter upon the care, repair and troubles of motors, also data of the various standard Westinghouse and General Electric motors and controllers.

Section IX. Operation, consists chiefly of a series of questions for the examination of motormen, instructions to motormen, and a classified schedule of piece work repairs for the motor repair shop.

Taken as a whole this volume is probably the best practical American hand-book that has yet been published for the man whose daily occupation is railroading. E. N. L.

Fowler's Electrical Engineer's Year Book and Directory of Light, Power, and Traction Stations, for 1906. Leatherette. Red edges; 4x6¼ inches, 643 pages and 17 pages of index, with many illustrations. Scientific Publishing Co., Manchester, England. Price 1, 6 net.

In looking over this book the reviewer is impressed with the large number of omissions, which an American would expect in a book of this kind. It is probable that the difference in the development of the industry in England will account for a number of the omissions, such as information regarding overhead line construction and the series alternating arc light system.

It is noted, however, that while the subjects of arc lamps, house wiring, the adjustment of copper brushes for dynamos and for motors, are treated with some considerable detail, there is no mention of method and means for testing high-tension cables or for locating faults in underground cables.

There are about twelve pages of formulae and theoretical information for the calculation of the hysterises and eddy current losses of transformers, the separation of the losses, the efficiency, and the ratio, but there is no method described for the calculation of the regulation of a transformer. Neither is there any mention or description of air-blast, oil-insulated, or water-cooled transformers.

There are a number of pages devoted to systems of distribution, and some interesting information is given regarding the comparative cost of a number of systems and the cost per K. W. of several high and low tension systems, but we find that all of the information which would assist an engineer in laying out a distribution system consisting of feeders and mains is contained in one sentence.

By a "Year Book" we understand that an edition is issued every year, in order to keep the book up to date, but we note that although there are some instructions for adjusting sight feed lubricators, there is no mention of self-oiling bearings.

We note that the Cardew hot wire voltmeters and the Kelvin graded tangent galvanometer are described, but there is no description or even mention of the Weston or similar types of portable meters.

In their description of high-tension switchboards they describe two of the earliest ones that were constructed, and fail to make any mention of the more recent types of electrically operated oil switches and controlling devices.

In the portion concerning alternators the compiler of the "Year Book" displays a lack of familiarity with the subject. In a diagram of synchronizer connections on page 294 a single synchronizing transformer is shown, with independent coils on the same core leading to the two alternators. It would be interesting to watch the operation of this transformer when the flux due to the two coils was in opposition, so that there would be no back E. M. F. Again, on page 319 there is the statement that "two similar single-phase alternators in series, one being driven as a generator, will drive the other as a motor." It is generally understood that a parallel connection is required for this purpose.

In several cases the proofreader has shown some carelessness; thus on page 383, under the head of "Definitions" in the "Board of Trade Regulations" the second line reads—

"The expression 'the Order' means the ...............,"

but the sentence ends abruptly without completing the definition.

Again, on page 257 we find the title "Circuit Breakers and Lightning Arresters," but there is absolutely no other reference to circuit breakers in the reading matter, although we find in the index that the subject is treated on the following page.

The interesting parts of the book to an American are the Board of Trade rules and, in the latter part of the book, the voluminous and valuable information regarding the capacity and equipment of the electric lighting and railway stations in London and in the provinces. This latter information is given in some considerable detail. Not only have they given the equipment and capacity of the boiler room and engine room apparatus, but also the system of distribution used and the frequency and voltage employed.

But when it is considered that the price of the book in this country, including duty and postage, would probably be less than $1.00, and considering all that there is in the book with its many tables, data and illustrations it is to be regarded as an excellent one, containing much useful information, and fully worth all that it cost

D. W. R.

Electric Power Transmisson. A practical treatise for practical men, by Louis Bell, Ph. D. Fourth edition revised and enlarged. Cloth, 6½ by 9¼ inches. 721 pages including 17 pages of index. 341 illustrations, and some full page half-tone cuts. New York, 1906, McGraw Publishing Co. Price, $4.00.

The third edition of this work came out about four years ago. The rapid progress in central station work and especially in high tension transmission is the raison d' etre of this new edition.

Like all other books by this author, this one is just what it claims to be, "a practical treatise for practical men." The book is not filled with scarecrow formulae or heavy mathematical exercises but contains clear descriptions and explanations of phenomena and of apparatus which makes it an excellent volume for general information on the subject treated.

The first chapters are devoted to a single and interesting treatise of elementary principles of electrical engineering and of general conditions of power transmission. A criticism might be made of the choice of efficiency curves on page 59. The "practical man" would conclude from this curve that the efficiency of a dynamo is higher than that of a motor until he has read several pages further and has there learned that the capacity affects the efficiency. This latter fact should be mentioned in connection with the curve.

Part of the chapter on transmission of power by direct current is devoted to a discussion of the merits of D. C. as opposed to A. C. transmission.

Then follows a short treatise on the phenomena of alternating currents. An unfortunate deviation from conventional practice occurs in the illustrations of lagging current and pressure waves. It is usual in such illustrations to assume time as progressing from left to right but in this case the backward direction of the Chinese is used, which is liable to lead to confusion.

Higher harmonics, what they are and how they affect the system, are well treated in the chapter on A. C. transmission. A general description of the design of alternators gives reasons for their mechanical arrangement. The subject of transformers is fairly well covered.

A. C. motors, synchronous and induction, form the subject of a chapter while another is devoted to rotary converters, motor-generators and rectifiers.

Then follow a few interesting chapters on engines and boilers, water wheels and on hydraulic development.

The organization of a power station, its design, illustrated by many examples, the transmission system, and so forth, all receive consideration, as do also auxiliary and switchboard apparatus, voltage regulators and the like.

In the chapters on the line and on line construction is a discussion of insulators, glass, porcelain, etc., line constants and their determination, lightning arresters, and underground cable, while methods of distribution, and various illuminants are also described. Costs and policy are treated under the heading of "The Commercial Problem," which is followed by a chapter on meters for measuring current.

The interesting final chapter closes with a table giving a list of American plants worked at 20,000 volts and higher. This table shows thirteen plants using 60,000 volts and fifteen of 40,000 to 60,000 while those of less than 40,000 volts are plentiful. An interesting illustration of present tendencies is offered by a comparison with the similar table in the third edition of this book. In this latter table were included also all American stations of 10,000 volts, still the total list contained a less number of stations than the present list in this latest edition which includes none of less than 20,000 volts. R. F. S.

Standard Telephone Wiring. By Fairman. 91 pages. 4½x7 inches. Leather bound. McGraw Publishing Company, New York, 1905. $1.00 net.

A handbook for telephone men containing various diagrams and embracing in some degree both magneto and common battery systems. The work contains some definitions of electrical units, and closes with an extract

from the rules of the National Board of Fire Underwriters so far as they govern signaling systems. The book is profusely illustrated, although it is to be regretted that the diagrams do not show standard forms throughout. and are not always clear as to what is intended to be shown. In the portion concerning troubles, eighteen different difficulties and cures are given, of which seven only apply to the common battery system, which is in extensive use today. S. G. McM.

PRACTICAL ALTERNATING CURRENTS AND ALTERNATING CURRENT TESTING. By Chas. F. Smith, Assoc. M. Inst. C. E., A. M. I. E. E. 6 by 8¾ inches. 437 pages and 5 pages of index; 204 illustrations, diagrams, etc. Scientific Publishing Co., Manchester, England. Price 6s. net.

The rapid development of alternating current systems has created a demand for and the production of a large number of books, such as elementary principles of alternating current work, alternating current machinery, alternating current testing, etc. This book was prepared to be of "special use to students in technical schools and colleges in connection with laboratory work, and to young engineers engaged in handling or testing alternating current machinery."

The text is divided into twelve chapters as follows: Chapter I, Alternating Electromotive Force and Current; Chapter II, Impedance; Chapter III, Power and Power-Factor; Chapter IV, Virtual Value of an Alternating Current; Chapter V, Effects of Capacity; Chapter VI, The Transformer; Chapter VII, Alternators; Chapter VIII, Synchronous Motors; Chapter IX, The Polyphase Circuit; Chapter X, The Rotary Converter; Chapter XI, The Induction Motor, and Chapter XII, The Analysis of Alternating Curves. But the clearest idea of the scope of the book is obtained by examining the list of 53 experiments which form the basis of the work. The first 21 experiments are all on work with electrical instruments and devices to give familiarity with fundamental principles and calculations. The diagrams of connections are very clear and are especially to be commended, because they use the conventional signs as recommended by the United States patent office. The applications, examples, and correlations given in the text, in connection with each experiment, are especially valuable to the student or to the young engineer. The following twelve experiments are devoted to quite a complete analysis of the operation, methods of working, and the efficiency of the transformer. Seven experiments are given to determine the characteristics of an alternating current generator. Three experiments are devoted to synchronous motor testing. Two experiments on three-phase metering. Four experiments with the rotary converter. Three with the induction motor. And one as a basis for the development of the Hayland diagrams.

Much valuable information is presented in graphical diagrams which are given of the results as determined with the apparatus used by the author. The graphical method has also made it possible to give a clear idea of variables without the use of higher mathematics. The direction of rotation in the diagrams is especially commended, because of the possibility of reference to books written by Mr. Steinmetz.

The Heyland diagram is used for the complete graphical analysis of the induction motor. The reviewers believe the more recent circle diagrams are to be preferred for work with students.

All the experiments are practical, making the book an excellent manual for the alternating current laboratory. The completed laboratory work does not detract from its value, because the equipment of any laboratory will vary enough to compel the student to familiarize himself with the behavior of the machinery he is handling. The book should be of use, not only to the student of the alternating current laboratory, but also to anyone who wishes a readable book from which he can get practical information of the operation of alternating current apparatus. R. N. & W.

THE WIRING HANDBOOK. By Cecil P. Poole. 84 pp. and 32 tables. 4½x8 inches. Leather. McGraw Publishing Company, New York, 1905. $1.00 net.

The book is said to be intended for the use of wiremen who have occasion to lay out their own work, and also for the use of engineers who make up wiring plans and specifications. This statement fully explains why the book contains rudimentary instructions and advice as well as more fully mathematical formulas. A very intelligent discrimination has been used by the author in restricting his work to the definite subject under treatment, and in both the mechanical and mathematical phases of its scope it is exact while being sufficiently broad for its purpose, and sufficiently narrow for the required condensation.

The book abounds in diagrams which are clearly drawn and are fully expressive. These are further admirable in their use of standard conventionals where possible, and in the use of clearly suggestive conventionals where no standard ones are available. The plates and tables which illustrate the work share with the letter-press and smaller cuts the excellence we are glad to indicate.

In a few pages, the rules of the National Board of Fire Underwriters,—which are presumed to control wiring in the United States,—are digested so that the matter required for guidance is not only handily present in one volume, but is more definitely illuminative than in the published pamphlets of the National Board itself.

The table of formulas is particularly pleasing, as it has a sufficient scope from resistance to admittance to enable frequently necessary determinations to be reached with quickness and with ease. S. G. McM.

PRACTICAL CEMENT TESTING. By W. Purves Taylor, M. S., C. E., Engineer in Charge, Philadelphia Testing Laboratories. The Myron C. Clark Publishing Co., New York, 1906. 6½x9¼ inches; cloth; 320 pages, including copious index. 142 illustrations and 58 tables. Price $3.00.

The treatment of the composition and constitution of cement in this book must be considered the very latest compilation on this division of the subject matter, tersely put.

The chapter on manufacture describes the several methods in a clear, concise and complete manner. The cuts of crushers, driers, ball, and tube mills, rotary and various forms of upright kilns are exceptionally good.

On sampling the author seems to have missed the mark some when he recommends the mixing of samples before testing. He justifies it by saying: "The separate testing of a number of samples, each taken from a separate bag, involves usually a large amount of unnecessary work." This so called unnecessary work might be obviated by testing separately for setting and soundness and by making the tensile tests and fineness on a mixture of the same samples. Practically, when tests for setting and soundness are made on a mixture of samples, some are good and some bad, the true nature of which is so disguised as to yield very inferior results.

The chapter on testing gives a short history of the development of cement tests. The chapters on Specific Gravity, Fineness and Tensile Strength are very complete. The method of mixing cement for tensile briquettes might be criticised some, though under his method good results can be obtained.

The chapter on soundness is exceptionally well written and contains a fund of information on the various tests for soundness and apparatus for making the test.

The chapter on chemical analysis is also very good, based on the author's experience, and giving the methods recommended by the Committee on Uniformity in the Analysis of the Materials for the Portland Cement Industry of the New York section of the Society for Chemical Industry which was indorsed by the American Society of Civil Engineers.

Appendices give the standard method of testing recommended by the Committee on Uniform Tests of Cement of the American Society of Civil

Engineers, the American Society for Testing Materials, and the New York section of the Society for Chemical Industry; also specifications recommended by the Board of Engineers U. S. A., the British Standard Specifications, and specifications adopted by the Canadian Society of Engineers.

The book contains a large number of useful tables, showing considerable research on the part of the author. The work as a whole is a valuable contribution, if not the best one, to the literature on cement, its manufacture and testing, but is particularly valuable to the man in the laboratory who is called upon to do the routine testing. It deserves a place in every engineer's library. P. Mc. A.

Practical Pattern Making. By Herbert Aughtie, A. M. I. Mech. E. Red cloth; 5¾x8½ inches. 166 pages and index. 237 illustrations. The Scientific Publishing Co., Manchester, England. Second edition. Price 4 shillings net.

This book is well arranged and should be of considerable value to pattern makers and those learning that trade. The illustrations are good, and the descriptions of the several parts or kinds of work referring to the illustrations make the whole matter clear and easily followed.

The author gives some account of the moulding operations, a knowledge of which is so necessary to the pattern maker. There are some who strongly advocate practical instruction in the foundry to the apprentice, as giving the knowledge that is so necessary to a good pattern maker. This instruction does not necessarily include that of operation of the cupola, the charging and melting of the metal, but refers more particularly to the methods followed in making the mould for the metal,—whether in "green sand", "dried sand" or "loam",—that the possibilities, as well as the limitations of the moulding floor, may be known to the pattern maker. With such knowledge the workman can so much more intelligently plan how a pattern for any casting shall be "laid out" and made. The pattern maker needs to do a good deal more than merely make a wooden model of the object to be cast in metal, for unless there be a sufficient knowledge of the art of making the mould, and a comprehension of the work in the machine shop subsequently, there will be much trouble from difficulties encountered in preparing a mould that will give a good casting, and that can be properly worked in the machine shop.

The contents of the book are divided into thirteen chapters, which appropriately subdivide the matter into such parts as would logically follow in a course of instruction in this trade. The last chapter is short, and relates to machinery for use in a pattern shop. In the opinion of the reviewer, this could have been enlarged to advantage, and not have confined the illustrations of pattern making machinery altogether to advertising cuts of one maker. An enlargement of the text, on the design, construction, operation and capacities of the tools, with floor space required, would be a valuable addition to this book, which, however, has many excellent points, and is valuable for a technical library. W.

Ventilation of Buildings. By William G. Snow and Thomas Nolan, New York D. Van Nostrand Company, 4x6 inches; boards. 83 pages. Price 50 cents. Van Nostrand Science Series.

The matter of this book is divided into three sections,—I. General Principles of Ventilation, occupying 43 pages. II. Different Systems of Ventilation, 20 pages. III. Ventilation of Different Kinds of Buildings, 18 pages.

The authors of this little book desired to condense into a small compass a statement of the general principles of ventilation, and their application under varying conditions and requirements.

As a preliminary survey of the subject of ventilation, and one that takes up the principles and application of ventilation under various condi-

tions, this book is well written, and the various heads follow in their proper sequence.

The book is valuable to one about to study the ventilation question, as it gives a complete outline of the various points which can be studied more comprehensively in more exhaustive treatises, while freeing the preliminary work from formulæ which are apt to prove more or less confusing until the result to be obtained is firmly fixed in the mind.

The reviewer thinks that in this book the authors have fully accomplished what they set out to do, and have brought out a book that is rightly called a "primer on the subject for those who wish to be told simply and briefly what is considered today the best practice." J. B. B.

Modern Tunnel Practice. Illustrated by examples taken from recent actual work in the United States and foreign countries. David M. N. Stauffer, M. Am. Soc. C. E., Vice-President. Engineering News Publishing Co. Cloth; 6¾x9¾ inches. 314 pages, including index; 138 illustrations, and several tables of costs, etc. New York, 1906. Engineering News Pub. Co. Price $5.00.

This recently published book contains, as the title appropriately indicates, a thorough review of the construction of the more prominent tunnels and kindred structures of modern times. A great many of the descriptions have appeared from time to time in the *Engineering News* during past years, but are here boiled down and trimmed up to make them suitable for an engineer's handbook.

The author has certainly succeeded in providing a vast array of facts and information for engineers and contractors upon this subject. Among them may be mentioned general hints on location, explosives, blasting, shaft sinking, and various methods of driving and timbering; on arch centering and tunnel shields; on concrete mixers; on cost data of tunneling, steam shovel work, concrete lining, borings and air-locks; on different methods of ventilation; on sinking shafts by the freezing process, and the water proofing of concrete.

Among the engineering works described are the following: New York Subway, East Boston Tunnel, Blackwell Tunnel of London, St. Clair Tunnel, the Twin-tube under the Harlem river, the Pennsylvania-Hudson River Tunnel, the Orleans Railway Tunnel in Paris, the Metropolitan and the Cascade Tunnels, and, the longest of all, the Simplon Tunnel.

The book contains a large number of excellent illustrations to make more clear the more than 300 pages of printed matter. In an appendix is a glossary, which is very complete, of technical terms used in tunneling that is a valuable addition to the book.

It might be added that the utility of the book would, perhaps, have been enhanced had all dimensions shown in the description of the Simplon been reduced to English units—feet and inches—and thus rendering this matter more comparable with the descriptions of other tunnels, and easier of comprehension to the majority of readers.

The book, from the standpoint of the printer, is almost without fault. However, there is one error, in that the page heading, "The Construction of the Simplon Tunnel," has been carried forward some pages too far. The alphabetical index, as well as the index by chapters and of the illustrations, is up to the usual high standard of the *Engineering News*.

The book fills a distinct field of its own—a field which is forging to the front rank in engineering problems—and, therefore, it should have a place in the library of every civil engineer. S.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for February, 1906, we have the pleasure to report the following additions to the library and gifts from donors named:

### MISCELLANEOUS GIFTS.

Myron C. Clark Publishing Co., New York, Practical Cement Testing, by W. P. Taylor. Cloth.

Probst, E., Vienna, Austria, Engineering Construction at the World's Fair, St. Louis, 1904, and the construction of the great buildings there.

Godfrey, Edward, Pittsburg, Pa., Tables for use in Structural Engineering, 1905. Leather.

Michigan State Board of Health, 31st Annual Report of the Secretary, 1902-3. Cloth.

Chanute, O., M. W. S. E., Chicago, Part 2, Volume III, of Whole Vol. XLVIII, Smithsonian Miscellaneous Collections. Pamphlet.

Harbor Commission, City of Chicago, Report for 1905. Pamphlet.

McGraw Publishing Co., New York.
- Electric Power Transmission, by Bell, 4th edition. Cloth.
- Wiring Handbook, containing labor-saving tables, 1905, and Underwriters' rules, by C. P. Poole, 1905. Morocco.
- Standard Telephone Wiring, by Fairman, 1905. Morocco.
- Practical Electric Railway Handbook, by Herrick, 1906. Mor.

Scientific Publishing Co., Manchester, England, Engineering Tables and Data, by Pullen. Cloth.

D. Van Nostrand, New York, Ventilation of Buildings, by Snow and Nolan, 1906. Boards.

Engineering News Publishing Co., New York, Modern Tunnel Practice, by Stauffer, 1906. Cloth.

McCullough, Ernest, M. W. S. E., Chicago, The Business of Contracting. Pam.

Sanitary Engineering Co., New York, Crematories for Garbage and Refuse. Pamphlet.

University of Wyoming, Laramie, Wyo., The Scientific Spirit, by Victor C. Alderson. Pamphlet.

Wallace, J. F., Chicago, M. W. S. E., Statement regarding the Panama Canal and Panama R. R. Pamphlet.

Commissioner of Public Roads, Trenton, N. J., Twelfth Annual Report, 1905. Pamphlet.

Miller, Hiram A., M. W. S. E., Chief Engineer Charles River Basin Commission, Boston, Third Annual Report, 1905. Pamphlet.

Tratman, E. E. R., M. W. S. E., Chicago.
- Proceedings 25th Annual Convention American Water Works Assn., 1905. Pamphlet.
- Proceedings 15th Annual Convention Association of Railway Superintendents of Bridges and Buildings, 1905. Pam.
- Current Meters on the Cars of the Street Railways at Frankfort, Germany. Two pamphlets, in French and German.
- Concrete Building Blocks, by W. S. Newberry. Pamphlet.

Concrete Construction, its Fireproof Qualities. Pamphlet, March, 1906, issue Engineering-Contracting and Roadmaster and Foreman.

Annual Report Dept. of Railways and Canals, 1903-4, with accompanying maps, Dominion of Canada.. Pamphlet.

Railroad Gazette, Chicago, 19 pamphlets, Journal W. S. E. (back numbers).

Also Proceedings Railway Club of Pittsburg, 1902-3. Leather.

Proceedings Traveling Engineers' Association, 1905. Leather.

Ball, Chas. B., Chicago, 15 pamphlets and one bound volume.

Operations of Engineer Department, District of Columbia, for the years 1885, 1886-7, 1888-9, 1891, 1892, 1893, 1895, 1896, 1897, 1901.

Reports of Commissioners of Engineer Department, District of Columbia, for the years 1880, 1888, 1894, 1898 (vols. 1 and 2).

## EXCHANGES.

Michigan Technic, Ann Arbor, Mich., semi-annual publication of the Engineering Society U. of M., Vol. 19, No. 1. Pamphlet.

American Society of Civil Engineers, New York, Irrigation System of Ontario, Cal.—Its Development and Cost, by F. E. Trask. Pam.

University of Wisconsin, Madison, Wis., Bulletin No. 106, Engineering Series. Sources of Water Supply in Wisconsin, by Kirchoffer. Pam.

Association of Railway Superintendents of Bridges and Buildings, Proceedings 15th Annual Convention, October, 1905. Pamphlet.

Chicago Board of Trade, Geo. F. Stone, Secretary, 47th Annual Report, 1904. Cloth.

Institution of Mechanical Engineers, Proceedings, June, 1905, No. 3. Pam.

Chicago Historical Society, Charter, Constitution, By-Laws, Membership List, and Annual Report, 1905. Pamphlet.

New Jersey Sanitary Association, Lakewood, N. J., Proceedings, 31st Annual Meeting, 1905. Pamphlet.

Massachusetts Board of Railroad Commissioners, 37th Annual Report, January, 1906. Cloth.

American Mining Congress, Denver, Proceedings 6th and 7th Annual Sessions. Pamphlets.

American Society of Civil Engineers, Constitution and List of Members, February, 1906. Cloth.

American Lumberman, Chicago, History of the Lumber Industry of America, by Defebaugh. Pamphlet.

Wisconsin Geological and Natural History Survey, Bulletin XIV, Economic Series No. 9, Lead and Zinc Deposits of Wisconsin, 1906, with accompanying maps. Cloth.

American Society of Mechanical Engineers, Advance Papers to be Presented at Chattanooga Meeting, May 1-4, 1906. Pamphlet.

Civil Engineers' Club of Cleveland, Annual Register and Constitution, April, 1906. Pamphlet.

U. S. Department of Commerce and Labor, Bureau of the Census.

Benevolent Institutions, 1904. Special Reports. Cloth.

Bulletins Nos. 29, 30, 31, 32, 33, 34. Pamphlets.

U. S. Geological Survey, Department of Interior, Reclamation Service.

Specifications, Nos. 73, 74, 75 ,76, 77, 78, 79, 80, 81, 82, 83, 85.

Third Annual Report, with maps. Cloth.

U. S. Geological Survey, Department of Interior.

Water Supply and Irrigation Papers, Nos. 148 and 150. Pam.

Bulletins, Nos. 272 and 274. Pamphlets.

Professional Paper No. 43. Pamphlet.

26th Annual Report Director of the U. S. Geological Survey to Secretary of Interior, 1905. Pamphlet.

The Normal Distribution of Chlorine in the Waters of New York and New England, Paper No. 144. Pamphlet.
Contribution to the Hydrology of Eastern United States. Paper No. 145. Pamphlet.
96 single maps, 3 double maps, topographic sheets.

National Bureau of Standards, S. W. Stratton, Director, 8 pamphlets.
The National Bureau of Standards, November, 1905.
Conference on the Weights and Measures of the United States, January, 1905.
Annual Report Director Bureau of Standards, 1904.
Organization and Work of the Bureau of Standards, June, 1904.
Bureau Circulars, Nos. 8, 9, 10, 11, 1904-5-6.

U. S. Department of Commerce and Labor, Bureau of Standards, Laws concerning the Weights and Measures of the United States, 1904. Pamphlet.

U. S. Civil Service Commission, 22nd Annual Report for 1905. Cloth.

J. H. Millard, U. S. Senate, Washington, Testimony in Investigation of Panama Canal Matters. Pamphlets.

Secretary Isthmian Canal Affairs, Washington, Report Board of Consulting Engineers for Panama Canal, with maps. Cloth.

U. S. Department of Agriculture, Forest Service, A Working Plan for Forest Service in Central Alabama, by Reed. Pamphlet.

U. S. Department of Agriculture, Weather Bureau, Recent Practice in the Erection of Lightning Conductors. Pamphlet.

U. S. Interstate Commerce Commission, Preliminary Report on the Income Account of Railways in the United States. Pamphlet.

## TRADE CATALOGUES.

American Electric Telephone Co., Chicago, Bulletins 10 to 26, inclusive. Pam.

E. H. Stroud & Co., Chicago, Crushing, Disintegrating, Pulverizing, Shredding and other Mining and Milling Machinery. Pamphlet.

F. W. von Oven, M. W. S. E., Aurora, Ill., Catalogue G25 of Love Bros., Engineers, Founders, Machinists. Cloth.

General Electric Co., Schenectady, N. Y., various Bulletins of Apparatus. Pam.

Sullivan Machinery Co., Chicago, Bulletin 51C, February, 1906. Pamphlet.

Crane Company, Chicago, 18 pamphlets, "advance circulars," March, 1905,—January, 1906. Two cloth bound volumes, "Pocket Catalogue of Steam Goods, etc., August, 1902."

Allis-Chalmers Co., Milwaukee, Bulletins Nos. 1050 to 1500. Pamphlets.

Goulds Manufacturing Co., Seneca Falls, N. Y., Goulds Pump for Fire Service. Pamphlet.

J. B. Strauss, M. W. S. E., Chicago, Catalogue of Strauss Bascule and Concrete Bridge Co. Pamphlet.

## ADDITIONS TO MEMBERSHIP.

NAME — DATE OF MEMBERSHIP.

Aegerter, Albert A., Active....April 6, 1906
Stock Exchange Bldg., St. Louis, Mo.

Baldwin, C. Kemble, Active....March 10, 1906
R. 749 Railway Exchange, Chicago.

Bunnell, W. C., transferred from Junior to Active.
Manila, P. I.

Draper, Robert S., Junior....March 9, 1906
6606 Perry Ave., Chicago.

Fitzpatrick, P. D., transferred from Junior to Active....April 17, 1906
Second and Monroe Sts., Paducah, Ky.

Freyn, Heinrich, Active....March 9, 1906
With Wellman-Seaver-Morgan Co., Cleveland, O.

Fulton, Wm. S., Junior....March 12, 1906
Hattiesburg, Miss.

Geraghty, Thomas F., Junior....April 5, 1906
1930 Surf St., Chicago.

Gilson, Charles B., Active....April 2, 1906
R. 1235 Monadnock Block, Chicago.

Hall, Merton G., Active....April 5, 1906
Centerville, Iowa.

Hemstreet, A. J., Active....
Texico, New Mexico.

Herrold, Geo. H., Active....April 5, 1906
With C. G. W. Ry., Red Wing, Minn.

Hotchkiss, Louis J., Active....April 6, 1906
Asst Engr., C. B. & Q. Ry., 209 Adams St., Chicago.

Judd, Frank R., Junior....March 9, 1906
6503 Kimbark Ave., Chicago.

Lurie, Arnold N., Junior....March 23, 1906
894 S. Kedzie Ave., Chicago.

Lyman, James R., Active....April 10, 1906
R. 1047 Monadnock Block, Chicago.

MacFarland, H. B., Active....March 23, 1906
5613 Drexel Ave., Chicago.

Maddock, Geo. F., Active....April 4, 1906
R. 824 Marquette Bldg., Chicago.

McVay, Albert D., Junior....March 14, 1906
478 E. 63rd St., Chicago.

Murr, Lindsley A., Junior....March 14, 1906
Greensboro, N. C.

Neikirk, John O., transferred from Junior to Active....March 15, 1906
523 Railway Exchange, Chicago.

Pettee, Horace J., Junior....April 8, 1906
506 La Salle Ave., Chicago.

Ralls, Melvin S., Active....March 12, 1906
4231 Lake Ave., Chicago.

Terhune, C. F., Active....March 9, 1906
806 Ellsworth Bldg., Chicago

Townsend, Gilbert, Junior....March 9, 1906
4217 Ellis Ave., Chicago.

Van Zandt, Paul C., Active....March 10, 1906
1522 First National Bank Bldg., Chicago.

Wagner, Walter R., Active....March 9, 1906
185 Dearborn St., Chicago.

## CORRECTED ADDRESSES.

Abbott, H. R., Engr., Metropolitan El. R. R., 1001 Royal Ins. Bldg., Chicago.
Anthony, F. D., 26 Sacrament St., Montreal, Canada.
Armstrong, W. C., Bridge Engr., C. R. I. & P. Ry., Chicago.
Ashmead, P. H., Care J. G. White & Co., 4 Exchange Pl., New York City.
Bainbridge, F. H., Engr. P. & Ft. P. Ry. Co., Pierre, So. Dak.
Beckerley, G. F., 2233 N. Alabama St., Indianapolis, Ind.
Bostwick, L. A., Res. Engr., P. S. & N. Ry., St. Mary's, Pa.
Brown, Paul G., Mgr., United Engineering & Contracting Co., 32 E. 33rd St., New York City.
Burdett, Samuel M., 931 Marquette Bldg., Chicago.
Evans, Louis H., Contr. Engr., Wm. Grace Co., 8070 Metropolitan Life Bldg., New York City.
Ewen, John M., R. 740 The Rookery, Chicago.
Finley, Wm. H., Asst. Chief Engr., C. & N. W. Ry., 215 Jackson Boul., Chicago.
Franson, Chas. E., Care James Stewart & Co., 135 Broadway, New York City.
Gardner, James W., with Allis-Chalmers Co., First Nat'l Bank Bldg, Chicago.
Hall, Julius R., 324 S. 64th St., Oak Park, Ill.
Harding, Geo. W., Contr. Engr., Modern Steel Structural Co., 308 Severance Bldg., Los Angeles, Cal.
Harvey, A. E., Dubuque, Iowa.
Hawks, F. W., C. & E. I. R. R., Postal Telegraph Bldg., Chicago.
Hazard, Wm. A., Res. Engr., C. & N. W. Ry., Green Bay, Wis.
Herr, Hiero B., 4221 Ellis Ave., Chicago.
Holmes, Frank, with Thompson-Starrett Co., Philadelphia, Pa.
Humphrey, F. W. L., Res. Engr., C. &. E. I. R. R., Vandalia, Ill.
Keerl, Harry D., Care J. S. Robinson, Wells St. Sta., C. &. N. W. Ry., Chicago.
Kieffer, H. Prime, 42 Broadway, New York City.
Lewis, James A., 383 Third St., Brooklyn, N. Y.
Lindau, Alfred E., Co. Engr., Expanded Metal & Corrugated Bar Co., 925-36 Frisco Bldg., St. Louis, Mo.
Lothholz, H. C., B. &. B. Dept., C. M. & St. P. Ry., Chicago.
Martin, Lewis M., Res. Engr., C. M. & St. P. Ry., P. O. Box 83, Watertown, Wis.
Mason, L. B., 4276 Moffett Ave., St. Louis, Mo.
McClure, Clyde H., Care Chicago Edison Co., 250 Washington St., Chicago.
Meier, Wm., 1616 Monadnock Block, Chicago.
Morehouse, L. P., Care Kenwood Club, Chicago.
Moss, Earl C., R. 621, 84 La Salle St., Chicago.
Morgan, Dwight C., Engr., R. R. & W. Com. of Minnesota, St. Paul, Minn.
Redman, C. H., with C. M. & St. P. Ry. Co., Portage, Wis.
Rust, H. A., The Quadrangle Club, 58th St. and Lexington Ave., Chicago.
Saner, C. C., 317 City Hall, Chicago.
Sawyer, Walter P., 4243 Calumet Ave., Chicago.
Scheible, Albert, 1729 Waveland Ave., Chicago.
Sexton, Joseph Price, 1623 Fourth St., New Orleans, La.
Sperry, H. M., Res. Mgr., General Signal Co., 1123 Broad Exchange Bldg., New York City.
Taylor, Wm. D., Chief Engr. C. & A. Ry., Railway Exchange, Chicago.
Thomas, M. E., P. O. Box 1568, Green Bay, Wis.
Towne, W. J., with C. & N. W. Ry. Co., R. 907-215 Jackson Boul., Chicago.
Wentz, Robert F., 701 National Bank Bldg., Allentown, Pa.
Williams, R. B., Jr., Williams, Proctor & Potts, 17 Battery Pl., New York.
Winslow, Benj. E., Engr. for Holabird & Roche, Architects, 1618 Monadnock Block, Chicago.
Yale, L. P., 131 Oak Ave., Aurora, Ill.
Zinn, A. S., Engr. of Constr. Michigan Central R. R., St. Thomas, Ont.

## DEATHS.

Parkhurst, H. W., (Past-President)........................April 7, 1906

Journal of the

Western Society of Engineers

VOL. XI. JUNE, 1906. NO. 3.

## ELECTRIC STREET CARS FOR CITY SERVICE.

Mr. M. B. Starring, General Manager, and Mr. H. B. Fleming, Superintendent of Maintenance Chicago City Railway.

*Presented before the Electrical Section, January 26, 1906.*

*Mr. Mason B. Starring*—Mr. Chairman, and members of the Western Society of Engineers,—any man ought to be very deeply sensible of the honor conferred by being permitted to address this Society, and of the opportunity offered to learn from you much that he has failed to ascertain, no matter how deeply may be his research, as many of you, no doubt, have given the subject much thought. I do not want you to think that I am entirely unqualified to talk about this kind of a car, for though I represent a company which runs some cable cars, I hope we may get into the front rank some day and have an all around up to date car equipment—and we will.

The street car business in the city of Chicago is exemplified in a story with which you are all familiar,—Four fellows went to college, all of ability. The first became a lawyer and men trusted him with their wealth and fortune and followed his advice; he knew his business. The second became a doctor, and men followed his advice and trusted him with what was dearer to them than their fortunes, their own lives and the health of their loved ones; he knew *his* business. The third became a minister, and men trusted him and followed his advice, believing the doctrines he laid down, and entrusted him with what was dearer to them than anything else, the eternal salvation of their loved ones and themselves. The fourth became a street railway manager, and any blamed fool knew his business better than he did himself.

That is the situation. This was forcibly brought to my mind a few days ago, and, if it had not been for the annoying features, the incident would have been amusing: A gentleman, educated in the medical profession, undertook, for a short period of time, the management of an admirably equipped street railway line. This gentleman arranged a schedule, satisfactory to himself only, cutting out certain stops, etc, thereby causing quite a mix-up for a little time, but fortunately his "management" was of a short duration.


FIG. I. EXTERIOR OF CAR, ARRANGED FOR WINTER SERVICE

The question is so often asked of us,—"Why don't you put on more cars?" That would look as though people thought one might go to one of the Department Stores and say "Send me a gross of street cars," and they would be delivered forthwith.

Different street railway managers have, naturally, varying tastes in regard to finish and coloring of the cars. I knew one very able and prominent manager who preferred a car with considerable ornamentation, and who chose red for its color; on the interior he had handsome carving and mirrors. That was a mere question of taste. Another gentleman, equally eminent, chose a car of a very subdued color, perfectly plain; another matter of taste.

Some credit has been ascribed to me in the selection of the car of which I am to tell you tonight, but the credit for the scheme belongs to Mr. T. E. Mitten, President of the Chicago City Railway Co. The details were carefully worked out by Mr. Harvey B. Fleming, Supt. Maintenance, and Mr. D. A. Faut, Master Mechanic.

The first thing to show you in connection with that car is Fig. 1, its exterior; the car, as shown here, is equipped for winter service. We desired to have some system of heating by which the cars would have a comfortable temperature at all times, and for the first time in this latitude the cars were equipped with double or storm sash. When the car is prepared for winter service the upper sash, having quarter-oval panes, makes a graceful appearance, something on the order of the Pullman parlor car. The cars are provided with transoms—22 pairs—which are worked by a worm gear, making it possible to close the transoms very tightly.

The car itself is 45 ft. 9 in. long over all; 9 ft. wide outside; 8 ft. 2 in. high on the inside; height, 11 ft. 10 in. from the rail to the trolley board.

It is equipped with side panels of sheet steel, so that when the cars are marred by wagons, etc., coming in contact with them, it will not be necessary to repaint an entire car and keep it in the shops for any length of time. The damaged sections are qiuckly removed and new ones substituted.

In Chicago we are troubled a good deal by so-called "hitching." There is an ordinance prohibiting it, but that does not prevent it; the result being that many accidents occur causing sorrow both to us and the people who get hurt, or more likely their parents, for of course most of the "hitching" is done by children. So we have eliminated any opportunity on the side of the car for anyone to stand, and the car as it is, is "hitch" proof, as shown in Fig. 5, which is the blind side of the car.

We have provided a vertical bar so as to divide the platform into two sections, in the hope of getting the people to move out one way and enter the other way, but it is a very difficult task to get them to do this, as they go in and out as they please, just as they do everything else here in Chicago.

The color of the car is green; the trimmings, orange, and the roof, buff. The only lettering on the side of the car, is the mono-

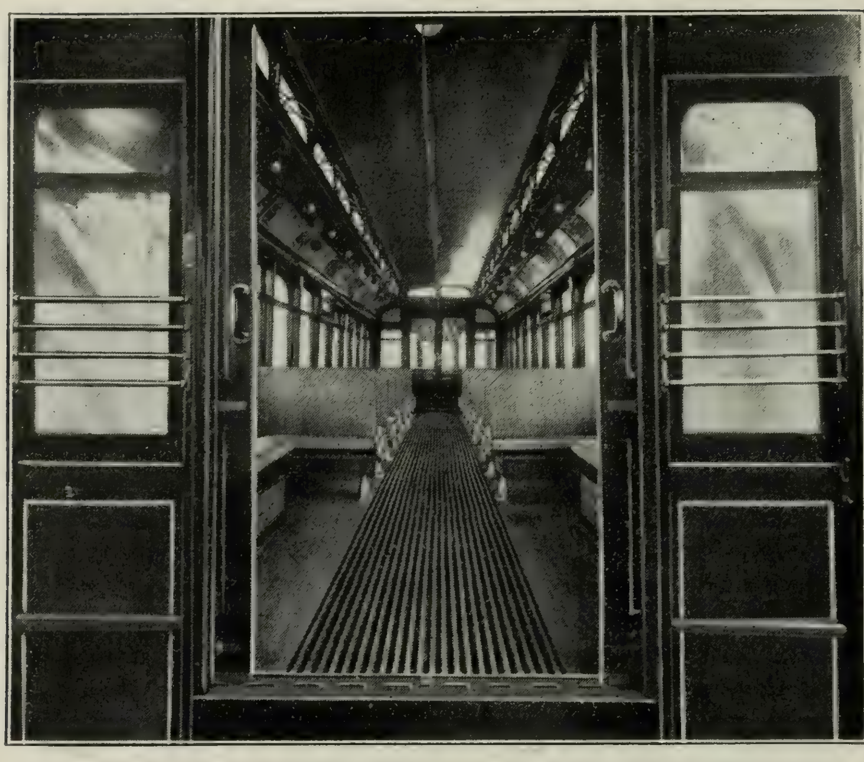


FIG. 2. INTERIOR OF CAR, ARRANGED FOR WINTER SERVICE

FIG. 3. INTERIOR OF CAR, ARRANGED FOR SUMMER SERVICE

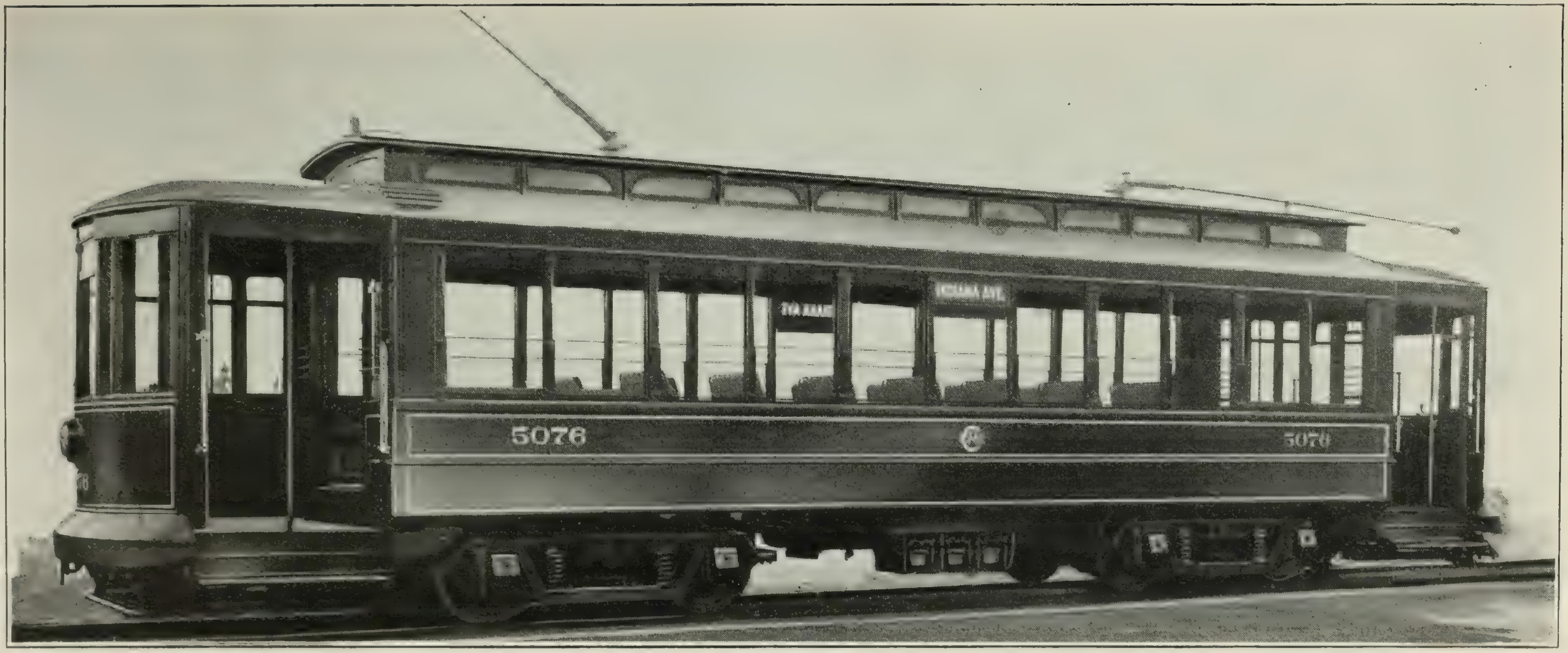



FIG. 4. EXTERIOR OF CAR, ARRANGED FOR SUMMER SERVICE


FIG. 5. EXTERIOR OF CAR ON BLIND SIDE, SHOWING ABSENCE OF FOOT-HOLDS

gram of the company, in aluminum, and the car numbers, also in aluminum. The foregoing gives you an idea of the outside of the car.

The view, Fig. 2, shows the interior of the car arranged for winter service. The seats run crosswise of the car in the center, and there are two longitudinal seats at each end. The car seats 28 people on the cross seats and 16 on the longitudinal seats near the doors, the total seating capacity being 44. The boxing under the longitudinal seats has been changed somewhat, and we have slanted it in, in order to give room for the heel.

So much has been said about the "Strap-Hangers League" that we decided to put no straps in the cars. This, however, brought condemnation rather than commendation. Four straps have now been placed beside each longitudinal seat, making sixteen in all.

The car as shown in Fig. 3 and Fig. 4 is for summer use, has the upper sash raised into the roof, and the lower sash dropped into a pocket; the pocket is so arranged that the sash acts as a lock, and the pocket cannot be opened until the window is raised out of its seat preparatory to lowering it into the pocket. This prevents having the pocket used as a receptacle for banana peels, etc.

When the cars are arranged for summer use the windows are raised or dropped, as the case may be, and the end car-body doors are removed; there are then no doors, and no windows apparent. In case of storm, the end windows can be raised, and the upper sash dropped and the lower sash raised out of the pockets, and, with the protection afforded by the vestibules, the car is sufficiently closed. Before the doors of the car-body were removed (in summer) the motorman would sometimes open the window in front of him, and then, in order to protect himself from draught, would close the car body-doors behind him, thus shutting out the air, but now that the doors are removed this is avoided, and a good circulation of air is obtained through the side opening.

There is a safety guard or screen extending half way up the window, for protection, but this is not well shown in the illustration. The front windows in the vestibule have also been dropped and the doors have been removed.

The vestibule window carries above it an illuminated destination sign, and the center side window, an illuminated line sign; in other words, the scheme is to put the destination on the ends of the car and the line on the sides. The reason for this is that, on the Indiana Avenue line, for instance, we have certain cars running to 51st St., certain cars running to 47th St., etc. The side signs on the car all read Indiana Avenue, but the ends state the destination,—whether 51st, 47th, etc. This is shown in Fig. 6, an end view of the car.

The motorman's window is carried in stops, so that he can raise it to any desired height.

The fender is of the Union Traction Company's type, except that there is a little rock provided to prevent the fender being pulled

out on the rear end, and persons riding on it.

The bumper has been filled in with wooden fillers; covered with sheet steel strips and is copied from those in use in the city of Buffalo on the International Railway.

The headlight is of cast iron, has a "bull's eye" front, and projects from the dash but four inches.


FIG. 6. END VIEW OF CAR

The width of the car was a question which puzzled us a great deal. We had in that question of width, to contend with many difficulties. The question came up, which was the safer, to have the cars very close together or to have them quite wide apart; the thing boiled itself down to about this: Either the cars must be so wide that persons could not stand between them and would not attempt to stand between them when passing, or else there must be suffi-

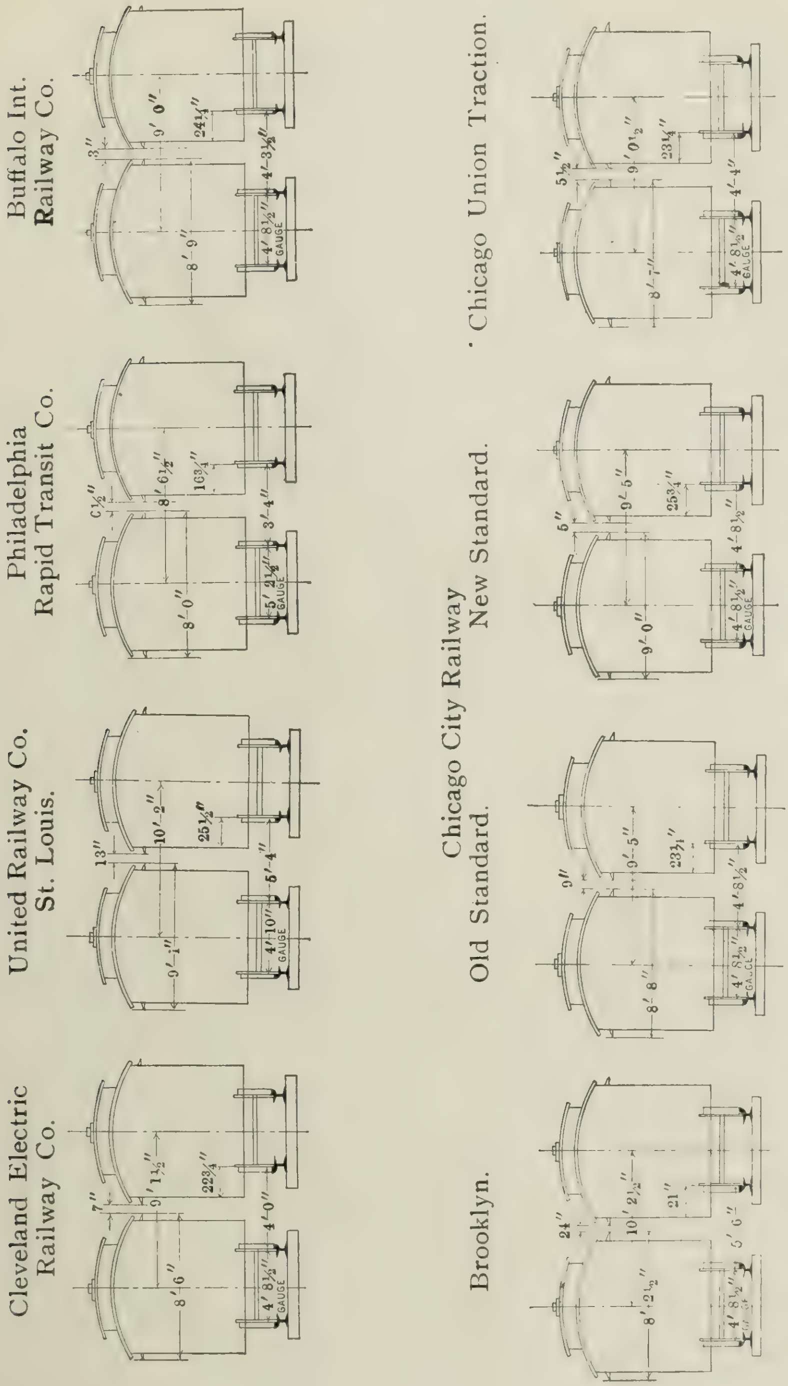



FIG. 7. CONVENTIONAL DRAWINGS, DIMENSIONS OF CARS, AND CLEARANCES ON DIFFERENT ROADS

cient room between them for persons to stand with perfect safety. During the discussion of this point, we canvassed all the large cities of the United States—Mr. Mitten and myself visiting many prominent cities, and coming to the conclusion that the safest plan would be to have the cars as close together as was practicable—and that plan was adopted. In looking up the subject, we had occasion to get comparative widths and comparative clearances in the different cities. These are shown in Fig. 7. The question of widening

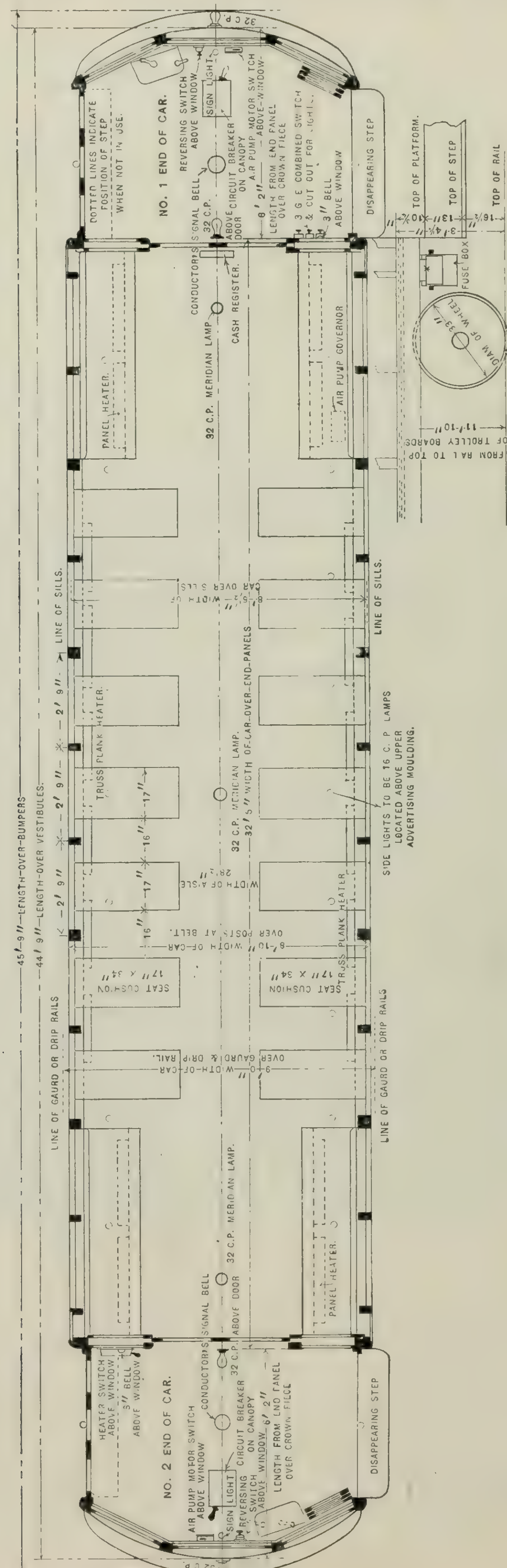



FIG. 8. PLAN OF CAR, SHOWING SEATS, HEATERS, SWITCHES, ETC.

the track centers was also considered, but as a large portion of our lines run on narrow streets, and the car being wide, in fact wider than any other car in the city of Chicago, it seemed inexpedient to do this, especially as we were up against the proposition of wagons alongside curbs, which would create a series of interruptions to passage of cars on the track; this was an additional reason for the adoption of the width of car finally chosen.

The car is designed with a "disappearing" step. The step is worked by a shaft on the car platform handled by the motorman, so that on the blind side of the car the step does not appear; as in Fig. 5; in other words, on one side there is no step at all; the channel iron is filled in and the bumper, as before shown, presents no opportunity to stand on it. In this way we have been able to eliminate "hitching." The step was designed by Mr. D. A. Faut, Master Mechanic of the Chicago City Railway Co., and it has been successful. The vestibule doors are folded up against the side of the car, so there is no room there. In the first type of the large cars, for instance those on Clark Street, the channel iron afforded a foothold, and we carried a large number of people who put their toes on the flange of the channel iron and were able to hang on in that way, and after once riding that way they liked it so well that they continued to do so ever after.

The electric phases of the car, the motor equipment, wiring, lighting, heating, etc., will now be described by Mr. H. B. Fleming, Superintendent of Maintenance, who is thoroughly competent to talk on these features of this "Standard Car."

*M. Harvey B. Fleming*—I did not expect to come here and address you in this way; I thought that I would be called upon simply to answer questions which might develop in the discussion of this car, but as long as Mr. Starring has very kindly left a part of the subject to me, I will try to make it plain. Possibly I may be able to explain to you our reasons for adopting these various changes from methods which had been pursued heretofore:

The view as shown in Fig. 8 is a plan of the lighting arrangement and location of seats, heaters and various switches in connection with the car. Some of these heaters are what we call the truss plank heaters and others are the panel heaters. The truss plank heaters are arranged between the cross seats; under the longitudinal seats we have the panel heaters. These heaters are all controlled by the standard 3-point knife switch, so that three grades of heat may be obtained, depending upon the temperature of the outside atmosphere.

The lighting scheme is also indicated in this plan. There are nine 16 c. p. lamps on either side of the car, and a circuit of lights down the center of the car. These large circles on the center line of the diagram represent 32 c. p. meridian lamps. The standard axle, you will note, is 5 in. in diameter at the motor bearings and 5½ in. diameter at the wheel fit and gear seat. We have found that anything smaller is not satisfactory for our weight of car. For the

20-16 C. P. LIGHTS AND 7-32 C. P. LIGHTS

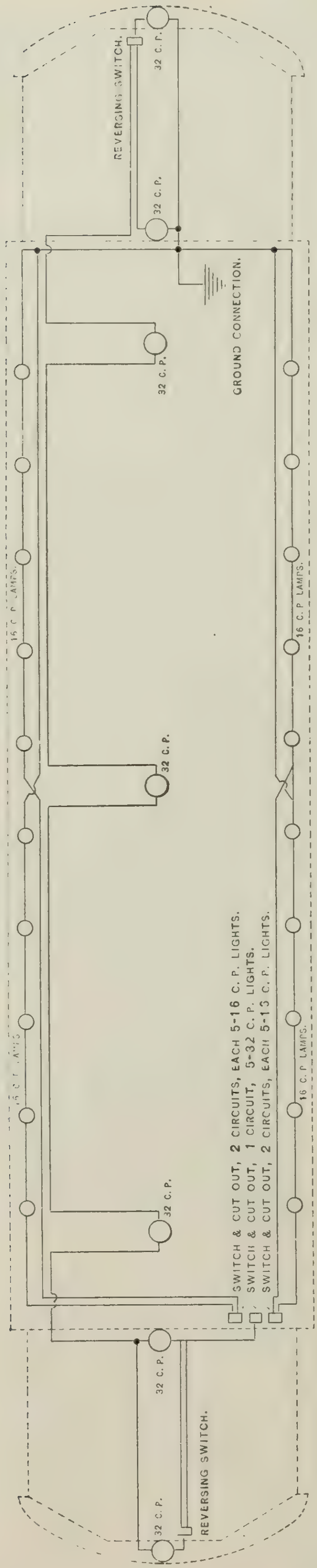



FIG. 9. CAR-LIGHTING CIRCUITS

ONE AIR COMPRESSOR WITH MOTOR, AND 20 DOUBLE-HEATERS

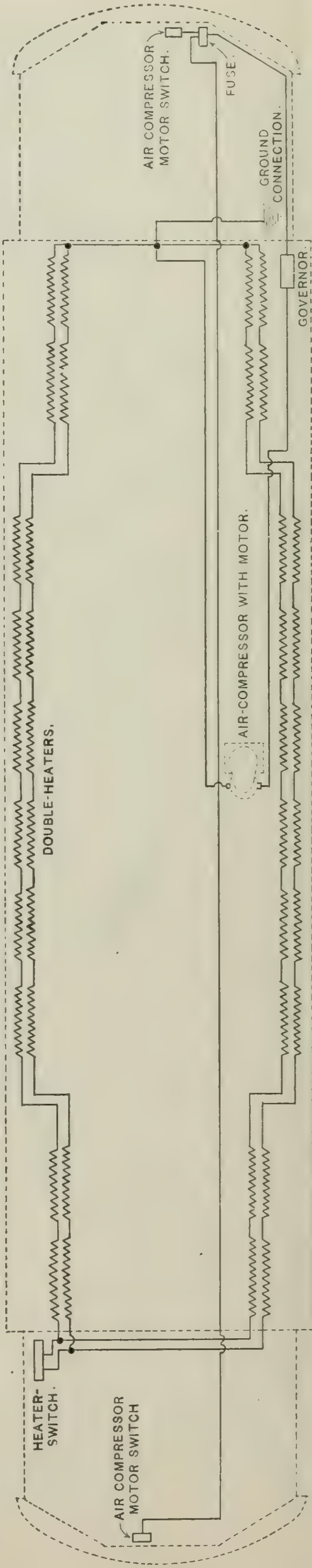



FIG. 10. AIR COMPRESSOR AND HEATING CIRCUITS

TWO K 28, B CONTROLLERS AND FOUR MOTORS

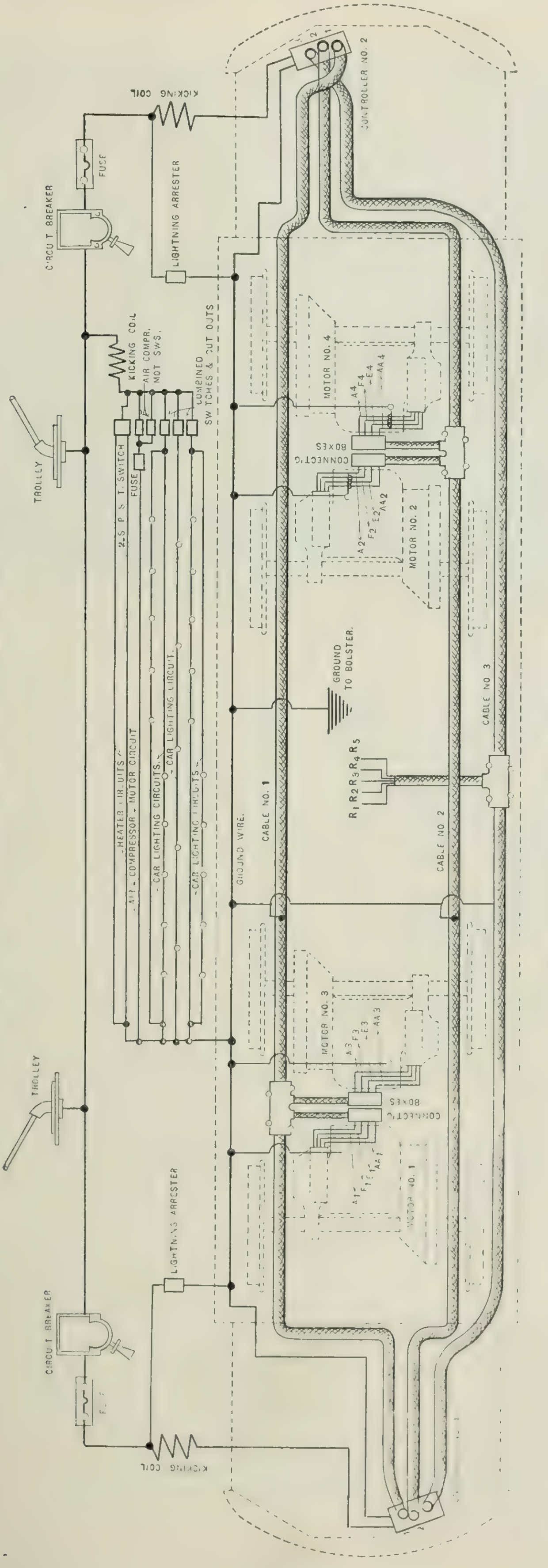



FIG. 11. GENERAL CAR WIRING

signal bell circuit, we have push buttons arranged at each seat for the use of passengers. We have found from experience, that it is desirable to put two dry cells in circuit; for in this way there is less trouble than by the use of one, as formerly.

The view, Fig. 9, shows a plan of the car lighting circuits in detail, and the method of wiring. As I said before, there are nine lights on either side of the car and seven down the center and one in each platform for the destination sign. Of course, there are always two of the center circuit of lights out.

The view, Fig. 10, shows the details of the air compressor and heating circuits; also the truss plank heaters between the cross seats and the panel heaters under the longitudinal seats.

The diagram Fig. 11, shows the general car wiring. You will note that the car is double ended and equipped with two trolleys, and the motors can be supplied with current from either trolley. The wiring is identical on either end. That is, each end of the car is equipped with a controller, a circuit breaker placed in the hood, and a fuse, etc. We take off a tap ahead of the circuit breaker for all of our auxiliary circuits,—that is, lighting, heating and the air compressor. In order to protect these circuits from lightning, we put in an auxiliary kicking coil. The lightning arrester tap is taken off ahead of the main coil. (This is the main kicking coil). The general scheme of the motor wiring is shown by these heavy lines, supposed to represent cables, N. 1, 2 and 3. This is only a diagram and does not indicate the position of the wires and cables on the car as it was actually worked out. We have three cables, of which No. 1 cable contains all the wires for Nos. 1 and 2 motors which are located on No. 1 truck of the car. We usually call No. 1 truck that one on the register end of the car. The wires for Nos. 3 and 4 motors are in No. 2 cable, and these motors are on No. 2 truck. The resistance wires are all in No. 3 cable. There is one feature here that is new. That is the introduction of the fuse in series with the circuit breaker. We have used this circuit breaker on about 205 equipments. They are similar to this one in design, and they have given good satisfaction, but in order to protect the motors and the car wiring, in case the circuit breaker should stick, we introduced a type of strip fuse. It is just a plain strip of copper with a hole in the center. There is another feature about the wiring of this car which I think is new (that is for the street railway type of car), and that is the manner in which the wires were installed. We used conduit wherever it was possible. The main cables and majority of the auxiliary circuits are in loricated conduit. The heater wires are in Sprague conduit, which is flexible and more easily applied for that particular work.

The view, Fig. 12, shows what we call a connection box: the motor leads, and the main conduits carrying cables 1, 2 and 3, running down through the center of the car under the floor. We take the motor lead taps through the "T" into the connection box where they are connected to a terminal. This terminal has a jaw very

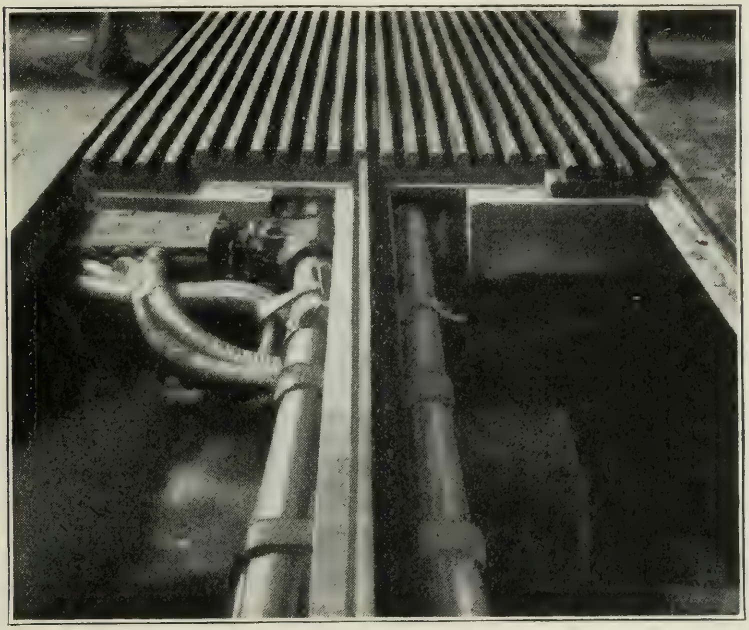


FIG. 12. CONDUITS, CONNECTION BOX, MOTOR LEADS

similar to a common switch jaw, and the blade of the switch is soldered to the end of the motor lead, to avoid all necessity for using connectors whenever overhauling the car. Any of you who are familiar with repair work on street cars will probably realize that this is quite an important point. One continually cuts the cables putting on new connectors, and then has to take them up or put some kind of insulation over them. We hope we have something here which will do away with all the annoyance caused by the old type of two-way connectors. All we have to do when we wish to overhaul the truck and jack-up the body is to loosen the two screw clamps on either side of the connection box; and take the lids off, when the leads can be removed just as you would an ordinary knife switch. The ends of the blades are upset, so it is not possible to pull them out endways and they are prevented from coming up sideways by an insulating block on the under surface of the lid.

The controllers are of the K-28 type, the chief difference from the K-10 type used heretofore being that the blow-out coil extends along the whole face of the cylinder, which does away with the arcing and burning of the fingers. The fingers are separated one from the other by fibre.

At the base of the controller is a junction box for the control wire. This design has proved quite satisfactory, and keeps all water from the motor controlling wires. Each cable has wires of different color, so it is very easy for a man making repairs to distinguish the wire it is necessary for him to connect.

This table explains itself. It gives the result of a study of the cars in different cities in America,—Car length over bumpers; over

# "ELECTRIC CAR FOR CITY SERVICE."

LATEST STANDARDS OF ELECTRIC CARS IN AMERICAN CITIES.

| PLACE | CAR LENGTH | | Platform Length | Width Maximum | Car Op. 1 or 2 Dir'ns. | SEATS | | | Length Cross Seat | Width Aisle |
|---|---|---|---|---|---|---|---|---|---|---|
| | Over Bumpers | Over Corners | | | | No. Cross | No. Long | Total | | |
| Brooklyn | 41' | ........ | ........ | ......... | 2 | 40 | 8 | 48 | 34" | 24" |
| Buffalo | 36' 5" | 26' | 4' 8½" | 8' | 2 | 0 | 34 | 34 | 0 | 0 |
| Chicago | 45' 9" | 32' 5" | 6' 2" | 9' | 2 | 28 | 16 | 44 | 35½" | 27" |
| Detroit | 41' | 29' | 5 and 6' 6" | 8' 1" over sills | 1 | 24 | 19 | 43 | ...... | ...... |
| Jersey City, Newark, etc | 42' 8" | 30' 8" | 6' includes bumpers | 7' 11½" | 2 | 35 | 8 | 43 | ...... | ...... |
| Kansas City | 43' 3" | 30' 7" | 5' 9" | 8' 6 | 2 | 36 | 8 | 44 | 34" | ...... |
| Nashville | 42' | 30' 6" | 5' | 7' 11½ | 2 | 28 | 16 | 44 | 34" | 23½" |
| Philadelphia | 37' over-crown pieces | 28' | 4' 6" | 8' 3" over posts | 2 | 32 | 8 | 40 | ...... | ...... |
| Queensboro, N. Y. City | 40' 8" | 30' 8" | 5' | 8' 6" | 2 | 28 | 16 | 44 | 37" | 24" |
| St. Louis | over vestibules 46' approx. | 33' 4⅜" | 3' and 7' | 9' 1" | 1 | 40 | 12 | 52 | 32" | 32" |
| Toledo | 41' 4½" | 30' 8" | 4' 8½" and 6' | 8' 2" | 1 | 28 | 16 | 44 | 34" | 26" |
| Average | 41' 6" | 30' 0½" | 4' 10½" | 8' 0¼" | .... | 32 | 15 | 44 | 34" | 25" |

corners; platform length; maximum width; whether the car is running in one or two directions; number of cross seats; number of longitudinal seats; total seats; length cross seats, and width of aisle. You will note from this that our aisles are exceedingly wide. The St. Louis type of car has a 32-inch aisle. Theirs is 1 inch wider than ours, our total width being 9 feet, their total width being 9 feet, 1 inch. The length of the cross seats of the Chicago cars is 35½ inches: of the St. Louis car, 32 inches. So we have provided more room for the passengers, in the way of seats. Aside from that one case, we have the widest aisle.

## DISCUSSION

*Mr. G. A. Damon*—(M. W. S. E.) (Chairman)—Why did you use electric heaters in connection with this car instead of hot water heaters?

*Mr. Fleming*—There were several reasons for adopting electric heaters; the results of a little study seemed to prove that they were more economical and less liable to get out of order in severe winter weather and they will not freeze up; with the electric heaters we are always ready to supply the necessary heat without having to carry coal or handle ashes; there is also no dirt, such as you would have from hot water heating or coal stove. You will probably remember the plan, showing the location of the heaters—the way they are arranged between the cross seats. It may remind you very much of a device on some of the Pullman cars, where the heating pipes are covered with a foot rest. These heaters answer for a foot rest for the person on the inside seat.

*Mr. Damon*—I have heard the objection that the guards around the heaters get very hot, and persons are liable to burn their clothes and shoes by getting against them.

*Mr. Fleming*—There has been some trouble, I believe, along that line, but most of it has been caused by persons throwing pins, hairpins, nails, etc., in on to the coils, short-circuiting same.

*Mr. Damon*—Would you mount the heaters any differently if you had to do it over again?

*Mr. Fleming*—No, I do not think I would. We are very well satisfied with the present arrangement. Such trouble as mentioned above does not happen very often.

*Mr. Damon*—You speak of having three different currents for the heating apparatus. Who determines the point of the switch at which the heater is to be set?

*Mr. Fleming*—The Operating Department,—our Chief Supervisor, Mr. Grinnell, and the starters. When a car starts out from the barns, a signal is put at the starting point, with a number on it, marked 1, 2 or 3, and the conductor is held responsible for the heater switch corresponding with that number.

There are two simple knife switches. If you throw in the first switch you get the first point of heat; pull that out and throw in

the second switch, and you get the second degree of heat, and when both are in, you get the third degree of heat.

*Mr. Damon*—Have any efforts been made to use the heat that comes from the resistance in starting the car, to heat the car?

*Mr. Fleming*—There have been attempts to do this, but I do not know of any that have proved satisfactory.

*Mr. Damon*—Returning to the questions of throwing hairpins, etc., through the openings in the guard over the heaters, would it not be dangerous to stick an umbrella in through one of the openings?

*Mr. Fleming*—No, I do not think the openings are large enough for that.

*Mr. Damon*—Of what material is the outside of the heater?

*Mr. Fleming*—It has a malleable iron case, enamelled inside.

*Mr. E. T. Munger*—(Metropolitan W. S. Elevated Ry.)—I was very much interested in hearing about that injunction box, used in connecting the motors. How large motors do you think it practicable to connect up in that way? Our motors are 160 H. P., two of them to the truck. Do you recommend a box like that, with that style of connector?

*Mr. Fleming*—I cannot see any objection. It would simply mean that you would have to make the switch jaws and connecting blade of carrying capacity sufficient to supply your motors. It would mean a larger box than we have at the present time. One thing I would like to bring up and that was the question of individual fusing of motors. Have you had any experience along that line?

*Mr. Munger*—We do not fuse our motors at all except at the trolley shoe, using the third rail, but we have a circuit breaker and a motor cut-out switch. In case one motor grounds, the circuit breaker is blown, the motorman resets and tries again; if it blows again he takes the controller handle and turns the motor cut-out switch, cutting out one motor. He then tries again, and if it is all right, he goes ahead. Often he changes to the other trolley and goes along.

*Mr. Fleming*—That is on the elevated equipment is it not, Mr. Munger?

*Mr. Munger*—Yes.

*Mr. Fleming*—I neglected to state the type of motor we use. They are of the G. E. 80 type, rated at 40 H. P., with four motors to each car, and the shell is split so that, when the car is run into the car house, you can drop the lower half and change armatures or fields, etc., without jacking up the car body. Four or five years ago we got two hundred new cars and equipped them with the G. E. 67 type, which is very much of the same type as the G E. 80. After they had been in service for a year the General Electric Co. got out what is known as the G. E. 70, designed for top inspection, and for a couple of years nearly everybody leaned toward the 70-type. Then we decided to get some new cars, and the question was what type would we buy,—one similar to the G. E. 67 or the 70.

After a great deal of discussion among ourselves, Mr. Faut and I were very much in favor of the G. E. 67 type, and in order to convince Mr. Starring and Mr. Mitten that we were right we all took a trip to a couple of cities where they were using the top inspection (type G. E. 70). We were able to convince them both that we were right, and that we could do anything with the G. E. 67 type in the way of overhauling and making repairs that was possible with the G. E. 70, and at the same time having the added advantage of being able to change a burned-out armature or make any necessary repairs to the motor without jacking the car body up from the truck. Since then I have noted that a large number of roads are going back to the G. E. 80 type of motor.

*Mr. Damon*—Have you any figures in regard to the power consumption for these cars, in kilowatt hours per car mile?

*Mr. Fleming*—We are making some power tests on these cars at the present time. We are not far enough along in these tests to give any particular results, but the actual power necessary to drive the car is going to average up closely in the neighborhood of 95 to 100 watt hours per ton mile, exclusive of auxiliary circuits.

*Mr. Damon*—What is the weight of the car?

*Mr. Fleming*—It is in the neighborhood of 26 tons, without load.

*Mr. Damon*—What is the average speed?

*Mr. Fleming*—Our schedule is in the neighborhood of ten miles per hour.

*Mr. Starring*—The schedule, to be exact, is about 9.57 miles per hour. There is no schedule up to ten miles.

*Mr. Fleming*—The average stops are about 5 to 9 per mile, depending on the line.

*Mr. Munger*—I would like to ask, Mr. Fleming, if that junction box is of your own design, or did you buy it?

*Mr. Fleming*—We had in use in Chicago, made in our shops (I do not know who made the first one) a little cast-iron box. We attempted to make of it a junction box, and several cars were equipped with them four or five years ago, for experiment. These have been in service ever since, and give good satisfaction. In visiting various shops (when we were ordering this last equipment of cars) we noted that the Master Mechanics of several other roads had attempted something on the same line, so, in taking the matter up with the General Electric people, we explained to them what we wanted in the way of conduit wiring, and submitted to them sketches showing the arrangement, and after considerable discussion this type of box was decided upon. I do not think it was any one man's idea, but is the result of experience of a great many different people. I am inclined to think that Mr. O'Brian, formerly Master Mechanic of the Chicago City Railway Company, got out the first cast-iron box used on our road. In Brooklyn, on the cars they built this summer, they have a small wooden box. I think it is rather crude and something of the same style has been used in Philadelphia. I do not know of anyone who has gone into the matter

as far as we have at the present time. We have had about 200 of these cars in service now for four or five months, and this box has given us no trouble. As far as I know, only three burn-outs have occurred in the box; two due to workmen leaving nails inside, causing short-circuit at the terminals in metal box, and the other due to water getting into the box.

*Mr. Damon*—This wiring you speak of,—is it something in advance of the recent rules issued by the National Board of Fire Underwriters?

*Mr. Fleming*—After deciding that the method described above was what we wanted, we took the matter up with the Underwriters' Association and received their approval. Our car wiring scheme is an approved scheme. I think it is better than anything I have seen along that line for a street railway car. For the interurban cars in the subway of New York the wiring is done along the same line, although probably more elaborate than ours. All of their wiring is in conduit.

*Mr. Warder*—(M. W. S. E.)—Would it be in place to inquire the cost of such a car as shown tonight?

*Mr. Starring*—A trifle over $5,500.00 apiece, counting in their assembling in the Chicago shops. We bought the trucks in Chicago, the motor equipment from the General Electric Co. and the car bodies from other builders outside of the city. The trucks were hauled over the traction company's tracks. The other parts came by freight. Including the freight and assembling, the car cost us probably in the neighborhood of $5,500.00.

*Mr. Schuchardt*—(M. W. S. E.)—I would like to ask Mr. Fleming what his experience has been with the lightning arrester on this car?

*Mr. Fleming*—The type of arrester we are using on that car is the M. D. type, of the General Electric Co.'s manufacture. It is giving very good satisfaction.

*Mr. Schuchardt*—Do you know of any case where cars have been struck by lightning on your service?

*Mr. Fleming*—On what we call the "red cars" we have had some trouble on account of lightning, but it never got into the motors. It would attack either the air governor or else the lightning circuits. Since the new cars have been in service we have had no electrical trouble on the cars whatever. I think it is probably due to the fact that we have protected all the circuits. The old type of wiring was not designed to protect them all.

*Mr. Schuchardt*—What was the reason for connecting the arrester on the ground side of the main fuse?

*Mr. Fleming*—One end of the car is always open, as far as the motors are concerned, but in operating the car both circuit breakers are always closed so that both arresters are always in service.

*Mr. Schuchardt*—Would it not have been better to have connected that on the counter side of the circuit breaker?

*Mr. Fleming*—I do not think so. The only additional protection you would get would be on your circuit breaker.

*Mr. Schuchardt*—As I remember the connection, the lightning would have to go through the circuit breakers and then strike off through the arresters.

*Mr. Cravath*—(M. W. S. E.)—I think I can explain that. If you put the lightning arrester in above the circuit breaker or fuse, if the lightning arrester should prove defective you would have a dead short circuit on your line, interfering with your station, and you could not locate it. There are one or two features connected with this City Railway car that are rather interesting to me. Mr. Starring called your attention to the fact that there were no straps in the car in the first place. The original idea of that was that, as there are hand rails on the back of the seats in the middle of the car, those who had to stand would be obliged to go to the middle of the car and thus not block the ends. It was a very good idea, but for some reason the people seemed to stand in the ends nevertheless, and to "kick" because straps were not provided.

The junction box I regard as a very marked advance in the art. Certainly there is great need for something which can be disconnected very quickly, when motors are taken off of the cars for repairs. All the connectors gotten out before this, have been nuisances, but it is hoped that this box is going to solve the difficulty. Some of the earliest equipments had what they called connection boxes for the motors which gave trouble at the binding posts and were abandoned. These later boxes have no binding post features—simply switch jaws—and it looks as if the difficulty had been solved.

Another feature on the cars that is quite interesting is the lighting arrangement. The cars have been equipped with frosted bulb lamps. The idea of that was, partly to give a better artistic effect, and partly to avoid the glare from the clear globes of a row of incandescent lamps down the full length of the car, which would be extremely hard on the eyes. The frosting of the lamps absorbs a certain amount of light, but the car is practically better lighted than if a clear bulb had been used. Personally I believe it is a good scheme, in car lighting where lights are located in rows over the seats, to use reflectors. Some street railway men object to the reflectors on the ground that they collect dust. But they are as easily cleaned as are the lamps themselves which the dirt falls upon in the absence of the reflector.

*Mr. Starring*—We equipped the first double truck car we had in Chicago with the clear bulb, and white glass bell to act as a reflector. We find the surface of the bells collect a great deal of dust, which adheres to them and requires a large force of car cleaners to keep them looking clean, and that was one of the factors which decided Mr. Mitten to install the frosted lamps without the reflectors.

*Mr. Damon*—There are two points not brought out, in which I

am somewhat interested. One is the use of the storm sash. I am curious to know whether Mr. Starring feels that that has been justified, in view of the fact that we are evidently not going to have any more winters in Chicago.

The other point was in regard to the finish of the hardware. At one time I made quite an effort to find out whether or not it would be possible to get a metal finish something on the order of what is called gun metal finish, but I found the only thing that could be furnished along that line, within reasonable cost, would be an oxidized finish, but I was assured it would wear off in a short time. The question still remains to be solved, whether or not we can find some metal which would have as permanent a finish as that of a gun metal watch case. In the case of brass or bronze finish, it must be quite an effort to keep the metal polished.

*Mr. Starring*—I congratulate Mr. Damon on being able to predict what Chicago weather will be.

We adopted the storm sash after considerable consideration. We find that the warm air is pocketed to a certain extent between two panes of glass and that a good deal of the force of our winds is broken,—that we do not have the cold pane of glass directly up against the warm interior of the car, and we believe we are enabled to maintain the cars at a more uniform temperature—the result has been satisfactory.

The heating of cars in Chicago is a difficult question when we run double ended cars. People get on at both ends, and they do not and will not close the doors behind them. We are putting across the door some lettering about 1½ inches high, reading "Please close this door." The Union Traction people followed the same idea, except they put an 8x6 sign in one corner of the glass door, bearing the same inscription. The door question certainly bothers us. But we feel we can furnish better heating with the storm sash.

In regard to hardware. We want, of course, to equip our cars in the most presentable manner with a minimum of cleaning expense, and we find that the oxidized finish is always presentable; and does not require constant polishing. The cleaning proposition was one of the causes for the truss plank heater being adopted, to clear every obstacle off the floor.

When the question came up about keeping the fittings clean, the matter was under consideration for some time, and we finally decided on the gun metal or oxidized finish. We have had the experience that where the hand grasps the hand rail, or where it grasps a door handle, the oxidation very rapidly wears off, and it becomes bright, but not objectionably so.

We are remodeling all of our 205 cars to make them conform as nearly as possible to the car you have seen tonight. There is one point we think we can improve. You noticed that we use an upright rod. That rod was painted, but we find the paint is wearing off. We are now going to enamel that rod, and we find we can do

that as cheaply as to paint it. We believe that kind of a rod will be quite satisfactory.

*Mr. Warder*—Referring to the "door-closing" sign, it seems to me that it should be so placed as to be read from the inside of the car, as those leaving the car should close the door after them.

*Mr. Starring*—The theory was that the passengers should properly load at the rear end. The light from the car illuminates the sign for those coming in, and it is conspicuous as one goes toward the light, but from the inside of the car one is moving toward a dark body, and consequently the sign is not so conspicuous. These are the reasons why we put it the way it is, to be read from the outside.

*Mr. Moller*—In reference to the signs. In the day time it is all right, as you can see the sign; but at night the sign should be illuminated, as it is very much to be desired that the sign be seen, in changing from one line to another.

I would like to know if anybody can give the comparative cost of using hot water heaters and electric heaters for car service.

*Mr. Starring*—The signs I think we will all admit have good sized lettering, and we use, of course, plenty of light behind them. We put the signs over the center window, as well as over the front and rear ends. They are on muslin, and are worked with a ratchet, being very easily changed by working the ratchet. The regulation is very smiple.

In regard to the comparative cost of heating, we have this worked out and have embodied it in a little statement which we have prepared. The estimate made for the cost of electric heaters was 73c per car per day of heating season; hot water, 80c per car, per day, of heating season. The cost, of course, in this matter was really not the determining factor. The determining factor with us was cleanliness, flexibility of use, and possibly the insurance, coupled with the fact that we had to use a double ended car and could not well carry the hot water heater on the platform. It was a hard question to decide, and there is no question but that both systems have marked advantages.

*Mr. K. B. Miller*—(M. W. S. E.)—I have had no experience whatever in car designing or manufacture, but when the subject of inside finish of the car was brought up, the thought occurred to me, why would not a bronze finish or one of the blackened iron finishes serve the purpose nicely?

*Mr. Starring*—I think the question of car finish is largely one of taste; one prefers gun metal finish, another polished brass, etc. We have found it desirable to furnish something that would not convey to the people the idea that it was used from an economical standpoint rather than for the artistic effect it would produce.

*Mr. Miller*—I know that people in certain lines of work have adhered to brass and bronze and excluded the iron because the iron was cheap, but they have returned to the iron, not because it was

cheap but because it afforded a durable finish, and one that many people consider artistic.

*Mr. Damon*—In regard to the question of noise of the car, those cars *are* noisy, and it has been said it is on account of the solid plate wheel. How serious an objection has that been, Mr. Starring, and have you had that question up?

*Mr. Starring*—The wheel question is a pretty strenuous one for an evening's discussion When I first entered the service of the City Railway Co. eighteen years ago, one of the first things I noticed was the noise. We had cable cars then, and the cable road


was then as progressive as the electric line is today. August Belmont said, in a recent address before the Chicago Real Estate Board, that when, 20 years ago, he was in Chicago the transportation system in Chicago was so far in advance of any other city that we had no followers; that today it is so far behind that we have no leaders.

It was told that we must stop the noise of the cable cars. The suggestion was made then that we should use a solid wheel. I have heard all sorts of expressions of opinion, and have yet to find anyone who can devise any means by which a 26-ton body can be propelled over a practically solid roadway—especially in the winter—without making a considerable degree of noise. Our friends on the Elevated Road have had a session with the city administration, with regard to the noise of the union loop, and I would be very glad if some of them could give us an expression of what they found to be the cause.

*Mr. Benj. Glover*—(Supt. Motor Power Metropolitan W. S. Elevated Ry.)—I can do nothing but repeat, in a very poor way, what

I have been trying to learn from one of your printed publications—a report on the Loop question, by Mr. Arnold—and I believe Mr. Damon could answer that question to better advantage than I could. The question is a new one to me; to Mr. Damon it is an old story. Will you answer that for me, Mr. Damon?

*Mr. Damon*—I think, if they would let us have our way about it, we would at least like to try something. I hope we may all get together, and by and bye we will have a noiseless and smokeless city.

When in Denver recently I saw in operation their electric street cars, which are ideal, having a central side entrance. A description of the car, with some illustrations, has been received and is here presented.

*J. A. Beeler*—(Vice-Prest. Denver City Tramway Co.)—The standard motor car used by the Denver City Tramway Co. is shown

herewith. Length over all 41 ft. 6 in.; width of aisle 23 in.; seating capacity 48; rattan seats in forward compartment, oak seats in rear compartment; one center entrance on right hand side of car, only. Entrance opens into forward part of rear compartment. This car is for all practicable purposes, semi-convertible, as sash can be let down and window-sills are low. Each car is equipped with four G. E. 58 motors, Christensen air brakes and 33 in. wheels. Weight of car 37,000 lbs. This type of combination car has been adopted as the standard by this company for the following reasons:

First—It is a safe car to operate. The conductor is practically at all times at the main entrance of the car, and even when engaged in collecting fares his average distance from the entrance is about one-fourth the length of the car. The fact that he is practically at all times within plain view of the main entrance tends to reduce the number of accidents. The central entrance also facilitates loading and unloading. Street railway men are all familiar with the passenger who, at the extreme end of the car, signals conductor, and then waits for the car to stop and walks the entire length of car to

alight. With this center entrance only, that passenger cannot walk more than half the length of the car.

Second—It is a car well adapted to Denver's peculiar climatic conditions. With cool nights the year around, and warm days, it is readily transformed from an open to a closed car. Even during the winter months there are many people who prefer to ride in the open air—in fact, the year around, the majority of people here prefer to ride in the open portion of the car. During the warm summer days the entire car is opened up, but during the evening the forward compartment is closed up, making a comfortable place for those who do not care to ride outside. In case of a sudden storm


it can be immediately made a practically closed car. During cold weather, in the winter months, those who desire heat may enter the forward compartment, which is heated electrically, while those who do not care to ride in a heated car may patronize the rear portion, where a certain amount of fresh air is always obtained on account of the wide center entrance being at all times open.

Third—It is a good type of car for collecting fares. For instance, if the conductor commences to collect at the front end of forward compartment, and works toward the entrance, by the time he is half way through the car he is at the entrance where passengers have to alight, consequently, there is no "dropping off" from the rear end of a long crowded car before the conductor has had a chance to collect fares. This item is of considerable financial importance.

Regarding use of trailers: We have found the use of trailer cars in connection with 4-motor cars very advantageous, the style of the trailer being similar to the standard motor car except that the roof has no upper deck, being simply a plain oval roof coming direct from the top slide plates, as shown in accompanying photograph of car No. 508. This car is the same width as standard motor car, is 38 ft. long over all, seats 44 passengers; has 30 in. wheels. In designing these cars, special attention was given to securing a strong and light car, capable of hauling a heavy live load. The entire body, as well as the trucks and wheels, were especially designed with this end in view. Weight of car complete, 12,300 lbs. This car will accommodate nicely, during rush hours and periods of heavy travel, 100 passengers. The advantages of the trailer are briefly as follows: They may be readily attached to the regular cars during rush hour in the morning and evening and during periods of heavy traffic; they require but one man (conductor) to operate, thus reducing wages of operation to one-half; they are safer than so many independent motor units on the streets, as they are handled by the regular motormen handling the motor cars, thus reducing the liability of collisions and accidents necessarily arising from the employment of new and extra motormen. Each trailer practically accommodates as many passengers as the motor car on the basis of rush hour traffic, allowing 100 to each car. This gives about 123 lbs. of dead load per each passenger on the trailer against 370 lbs. dead load per each passenger on the motor car.

Large economy in power is effected by the use of trailers. We find that the 4-motor car, without the trailer, consumes 2.5 K. W. hours per car mile. When hauling a trailer, the additional power required is 1.0 K. W. per car mile. This materially reduces the peak load and cost of necessary additional installation at power plant, storage batteries and copper for transmission.

Fixed charges and insurance are also reduced, materially, when the extra travel can be handled with trailers instead of additional motor cars. The first cost of a trailer is about 30% of the cost of a motor car, and repairs in about same or lesser proportion.

We have been operating trailers for two years, and have never had an accident attributable to them. It will be noticed that there is no possibility of a passenger stepping from one car to another, the center side entrance preventing this source of accident.

Photograph of Englewood open trailer with motor is sent you herewith. This line is operated in the morning during rush hour with a 4-minute headway, without trailer; through the middle of the day with a 6-minute headway, without trailer; and during the late afternoon and rush hour in the evening, on a 4-minute headway, with trailer. During periods of heavy travel trailers have been used all day to great advantage, without appreciably overloading the motors.

*Mr. Starring*—We have thought of trying an experiment, (but it is not practicable at present) of having the platform level with

the car floor, and putting instead of the folding vestibule door a sliding door, on the same principle of the Elevated car doors, thus making a car with an inclosed platform, and a car which has no double set of doors; such a proposition we hope some one may work out, and it may interest you to know that we had the thought in connection with that of putting on some sort of an electric lock so the door cannot be opened while the car is in motion. In that way it is hoped to eliminate many accidents arising from getting on and off moving cars.

There is another question which has troubled us a good deal, and that is, where and under what conditions should smoking be prohibited on a double ended car. So far we have not been able to work out any satisfactory plan.

# URBAN TENDENCIES OF POPULATION AS AFFECTING THE PROBLEMS OF ENGINEERS

Erastus G. Smith Ph. D., M. W. S. E.

*Presented March 7, 1906.*

The topic selected for this evening was suggested by the conditions of the occasion. It can hardly be expected that one called from the routine of college work should attempt to present matters of technical character to this body of men engaged in the varied engineering problems that the diversified life of the present day demands. I have, however, ventured to come to present the result of some reading and studies, in the hope that at least they may be suggestive and helpful to you in looking at some of the conditions confronting present practice, and the view which must be taken of all considerable engineering problems of the future. We find it profitable to halt sometimes in our active work and consider the conditions actually surrounding us, and determine whether we are approachng our particular problem in the wisest and best manner. Professional duties absorb all our attention and energies, and under their pressure we lose sight of the change in condition and environment taking place on every hand; especially are we too apt to look at the demands of the present and lose sight of what changed conditions may require of the very work we are setting in progress. This ability to foresee accurately the conditions of fifty years hence, and to make the view so clear that one will not be discredited at the outset as an impractical, visionary enthusiast, is one of the most difficult problems of the engineer. At the same time it is absolutely essential that he who builds at all should build well, and he who desires permanence in what is constructed shall so look forward in his plans that the future shall testify to the wisdom of his judgments. The service of the public, the large expense involved, the adequate personal return and one's undying reputation, are all involved in the question. It will be admitted that in this newer country we must not expect the impossible: few—none—would have been taken seriously had they affirmed that such a city as Chicago would have sprung from the rough prairie in a half century of time. We all, in our own experience, know towns and cities where no one expected, or had reason to expect, the marvelous development of the last two decades. The development of new and untried industries; the opening up of new and unsuspected natural resources; the strategic value of particular points in commerce and trade; the development of properties for the pleasure or health of men;—all of these indicate something of the unexpected problems arising for solution and must be met rapidly and as surely as conditions admit, but they are not what I have in mind. What I wish to bring out is the fact that there are certain tendencies to which we should all be alive,

which are sure and certain in their action, of permanent character, and vitally affecting all problems the engineer in public service is called upon to adjust. The particular one to which I invite your attention at this hour is the urban tendency in population. Weber in The Growth of Cities calls attention to the fact that in

1790

| | |
|---|---|
| The population of the United States was | 3,929,214 |
| The population of the cities of 10,000 and more was | 123,551 |
| The proportion living in cities of 10,000 and more was | 3.14 percent |

1890

| | |
|---|---|
| The population of the seven colonies of Australia was | 3,809,895 |
| The population of cities of 10,000 or more was | 1,264,283 |
| The proportion living in cities of 10,000 or more was | 33.2 percent |

The remarkable fact developed by comparison of the above tables is that in a century these two nations peopled by the same race, equally progressive and practical, in a new country with similar undeveloped natural resources and each independent of foreign influences, have developed a widely different mode of living. It is the difference between the eighteenth and the nineteenth centuries; it is the shifting from the country to the city life; the tendency of these two peoples, as of all western populations, is towards centralization and concentration.

Nor need we go so far afield to demonstrate this change in the habit of life of our own people. In the face of the tremendous strides forward in our population, both from the natural increase of the native-born and the influx of foreign immigration; in the face of the rapid westward movement of the people; with greater facilities for transportation by canal, steamship and railroad; with the easy communication by post and wire; notwithstanding all the independence of a rural life, the tendency of the population has been steadily toward the cities. The cities have increased in size and number and have steadily absorbed a large proportion of the population so that we read "in 1790 out of every 100 Americans only 3.35 percent were city dwellers; in 1890 out of every 100 the percentage was 29.2;" a relative number strictly according with the figures of the above table comparing America and Australia. It is interesting to note the steady westward progress of the great centers of population. In 1500 the great city of the world was Constantinople; in 1600 it was Paris; in 1800 it was London, with Paris in the second place, and Constantinople in the fifth position. In 1890 New York had risen to the second place with a population of 2,740,600 as against London with a population of 4,211,700; but during the years of 1850-1890, London had shown an annual increase of 1.96 per cent. and New York of 7.89 per cent. Who can prophesy what the onward westward march will be with a disparity of ratio of increase, especially when we recall that in 1890 the population of Chicago

had already reached 1,099,900, and for the same period, 1850-1890, the annual percentage of increase was 89.2 per cent?

In discussing the distribution of the American "urban populations" it is well to bear in mind that we are using the general term as adopted by the U. S. Census and regard all communities above 8,000 population as cities. As would be expected, the North Atlantic States have the largest proportion in the city dwellers and fewer villagers. The percentage of population residing in towns of more than 8,000 is as follows:

| | Per Cent. |
|---|---|
| North Atlantic Division | 51.58 |
| South Atlantic Division | 16.04 |
| North Central Division | 25.90 |
| South Central Division | 10.45 |
| Western Division | 29.74 |
| The United States | 29.20 |

Individual states vary greatly; thus there are living in cities of more than 10,000 population, in

| | Per Cent. |
|---|---|
| Massachusetts | 65.88 |
| New York | 57.66 |
| Connecticut | 41.86 |
| Illinois | 38.08 |
| Minnesota | 27.69 |
| Michigan | 23.90 |
| Wisconsin | 22.46 |
| Iowa | 13.62 |

It is of vital importance in this study to note whether the tendency is towards the small or great cities. On this point the paper by Mr. Carl Boyd, in the *Publications of the American Statistical Association,* on the "Growth of Cities in the U. S. during the decade 1880-1890" is of interest. In it he shows that:

| Population | No. of Cities | Per cent. increase of Population 1880-1890 |
|---|---|---|
| 200,000 or more | 12 | 36.87 |
| 60,000-200,000 | 28 | 63.07 |
| 30,000- 60,000 | 40 | 52.45 |
| 17,000- 30,000 | 81 | 53.72 |
| 11,000- 17,000 | 93 | 53.74 |
| 8,000- 11,000 | 102 | 47.30 |
| | 356 | |

This tabulation seems to prove that the tendency is towards the cities of moderate numbers as against the great cities. Certainly many of the smaller cities have moved forward at amazing rates during the decade under consideration. Thus, Minneapolis showed an increase of 251 per cent; Omaha 360 per cent; St. Paul 221 per cent;

Kansas City 138 per cent; Denver 200 per cent. Something of the same sort is shown from the census of 1900, but it will be noted that the greatest rate of increase is shown in the towns below the limit we are considereng as "urban" population. The following table is taken from the *Annals of the American Academy of Social Science* in an article on "The Significance of Recent City Growth" by Mr. Adna F. Weber, and in commenting on it Mr. Weber says:

> "The most rapid rate of increase of population in the United States is found in the villages or small towns (2,500 to 8,000 population) which are chiefly dependent for their prosperity upon manufacturing industry. The great cities—the centers of trade and commerce—nearly rival the villages in rate of growth. Moreover, the continued passage of villages into the ranks of small cities, and of small cities into the class of large cities, brings it about that an ever-increasing proportion of the people become residents of the larger cities in which political and social problems are of commanding importance."

It will hardly be wise for us to continue unduly this study at this time; enough has been introduced to make clear the tendency in our urban populations. The thoughtful engineer desiring to pursue the study further will find an admirable presentation in the monograph by Weber, to whom I am indebted for many of the figures introduced above.*

## The Application of the Probability Curve to Engineering Problems.

Leaving the consideration of the actual populations of cities for the present, we meet at the outset very practicable questions regarding the stability of growth and what guaranty there may be for the uniformity of development in the immediate or more remote future. Every engineer projecting public works of any sort, whether for water, sewage, transportation, or other public service, in his studies is sooner or later confronted with this perplexing problem, nor can it always be satisfactorily answered. The development of unexpected resources, either natural or commercial on the one hand and the application of improved appliances on the other, may seriously and materially modify opinions reasonably given at the time required. Mushroom growths come in a night and, alas, as often wither with the first bright sun. We need not recall the smartings of defeat, to projects we believed reasonably sure in their outcome.

Among the practicable methods, however, of studying the problem is that of the "Probability Curve," which I presume most of the members of this body have used as some time in their practice. In principle it is simple, being merely a referring of the data at hand to a system of ordinates. As an example we may introduce that

* The Growth of Cities, Adna Terrin Weber, MacMillan Co., 1899.

Percentage rates of increase, 1890 to 1900, of different classes of cities and villages:

| DIVISION | CITIES FROM | | | | | Rural Remainder | Entire Population |
|---|---|---|---|---|---|---|---|
| | 100,000 and over | 25,000 to 100,000 | 8,000 to 25,000 | 4,000 to 8,000 | 2,500 to 4,000 | | |
| New England | 30.1 | 36.2 | 26.4 | 16.1 | 14.7 | *2.0 | 19.0 |
| N. Y., N. J., & Pa | 32.6 | 33.3 | 35.5 | 44.9 | 45.4 | 3.4 | 21.6 |
| Northern South Atlantic | 18.5 | 16.4 | 28.3 | 39.6 | 26.7 | 13.3 | 15.7 |
| Southern South Atlantic | .... | 25.0 | 28.7 | 52.4 | 46.6 | 17.6 | 19.6 |
| Eastern North Central | 45.2 | 31.0 | 32.1 | 35.5 | 36.5 | 6.1 | 18.6 |
| Western North Central | 21.9 | 24.5 | 20.7 | 17.4 | 31.9 | 13.4 | 15.8 |
| Eastern South Central | 36.1 | 19.8 | 21.9 | 32.9 | 48.1 | 15.5 | 17.4 |
| Western South Central | 18.6 | 34.2 | 38.5 | 66.1 | 84.3 | 37.5 | 37.8 |
| Rocky Mountain | 25.4 | 66.2 | 64.7 | 68.3 | 64.3 | 38.6 | 42.1 |
| Utah, Nevada and Arizona | .... | 19.4 | 9.6 | 35.3 | 35.3 | 28.8 | 27.6 |
| Cal., Ore., and Wash | 27.4 | 55.3 | 38.1 | 72.6 | 24.9 | 19.2 | 28.0 |
| U. S. | 32.8 | 31.9 | 30.9 | 33.9 | 36.5 | 13.8 | 20.7 |

*Decrease

Significance of Recent City growth by Weber.
Annals of American Academy of Political & Social Science, vol. 23.

used by Mr. Flad in the reports to the Water Board of St. Louis, in which he endeavored to show the magnitude upon which the waterworks system in that city must be based to adequately meet the needs of the future; it also shows the rate of growth of St. Louis as compared with other cities of the U. S. Such a curve, however, is not a simple matter to establish; data are lacking and must be supplied at the cost of prolonged study, or the number of definite data is limited and of doubtful accuracy, or must be materially modified and interpreted by eccentricities of growth. The more such periodic data can be multiplied, the more sure are the results, and at best the probability curve is to be regarded as merely an indicator of what will actually obtain. With all of its faults it remains the best agent the engineer has at hand, and is worth all of the labor and study entailed in its preparation and projection.

As an illustration of the use of this method of forecasting the requirements of a service, and how far we are justified in its use, I would refer you to a prophecy made concerning the water consumption of the city of Rockford, Ill., and the fufilment of the same. Rockford is, as you all know, one of the thriving inland towns of this state. Its people are thrifty and industrious; its manufactures are varied; there have been no sudden and unexpected developments of a speculative nature; it is a good, solid, representative city, with substantial interests managed with care, and, with the exception of the depression of 1893, which especially affected its co-operative manufactures, its growth has been steady and uniform. In 1891 a Commission, consisting of the eminent engineers Mr. J. T. Fanning, Mr. D. W. Mead, and Mr. D. C. Dunlap was appointed to investigate and report upon a much needed additional water supply for the city, and their report was returned in November of that year. In that report the probability curve was used to fix the probable growth of the city and the probable daily consumption of water per capita, for a series of years.

There were available but a few national and school census enumerations covering the period since the year 1850, upon which to base any estimate of the population and project the probability curve. From this curve it was possible to determine quite exactly the population for any one particular year intervening between the periods given, and from it to tabulate the consumption of water per capita, but more important than this, by projecting the curve a prediction was made of the population of the city of Rockford for a succession of years until the year of 1905. The data upon which the curve was based were few and some of them of questionable accuracy. Below is given the full tables as originally printed in the report and alongside the population of Rockford at the census of 1900 to show how nearly the estimated population has been met.

Table of Population, City of Rockford, Ill.

| | Actual | Estimated |
|---|---|---|
| 1850 | 2,093 | |
| 1860 | 6,979 | |
| 1870 | 11,049 | |
| 1877 | 12,738 | |
| 1880 | 13,129 | |
| 1884 | 19,533 | |
| 1887 | 22,217 | |
| 1890 | 23,584 | 24,600 |
| 1893 | | 28,940 |
| 1897 | | 35,177 |
| 1900 | 31,051 | 40,722 |
| 1903 | | 47,141 |
| 1905 | | 51,972 |

Of course this table does not prove anything one way or another; it is introduced merely as an interesting illustration of the use of the method and its value in throwing some light on the future of population, with which every engineer must reckon.

## The Causes of Urban Populations.

It is of importance for the engineer to inquire as to the causes of the urban tendency in populations, their permanency and effects, as by the proper understanding of these can they be intelligently applied in any given locality, and full value assigned in determining his methods of procedure. The occupations of mankind fall into five general classes: (1) Extractive, (2) Productive, (3) Distributive, (4) Service, (5) Independent. The last two classes, while embracing a large proportion of the community, nevertheless do not essentially control the "drift to the cities." They include domestic servants, professional men and women, students and those of independent incomes. Wealth always drifts to the cities, and those dependent upon others for their support naturally must live in close association with those upon whom they rely for such support. These two classes constitute what Adam Smith calls the "unproductive" classes in the community. The first class, the "extractive," includes all workers living on the natural resources of the country, as farming, mining, and the like. The development of this class tends directly away from urban life and measurably balances the rapid gravitation to the cities. It is well-known that the tendency is away from these occupations, but it is not necessary to analyze fully the elements determining such tendency. The farmer not very many years since was a small community to himself—producing all he needed for his support—food, fuel, and even his clothing. Now, however, he is a member of the community, drawing his living from the soil and exchanging his products for his wants. This changed condition of living, the combination of the farmer with the larger community, the increase of farming machinery which requires less and less of hand

labor to operate the farm, the larger yield from the farm, the use of artifical fertilizers, the cutting of the wastes in selling of the product, all in their own way tend to diminish the need for hand labor, and the result is the inevitable drift of this surplus from the farm to the centers of population.

There are then two great classes directly contributing to the urban populations, the productive and distributive, and whatever relative value we may assign to them, there are at least three great positive causes with which the engineer must reckon.

1. *Commerce.*—Tade and barter have been a part of life since history began.

> "Trade was promoted by religious assemblies. From very early times men have gathered to celebrate the memory of some hero by funeral games, and this has given the occasion for meeting and trading; so that fairs were held annually at places of burial. Medieval towns grew up around shrines, and monasteries were built at the graves of early martyrs. Other towns grew up around forts or the castles of the feudal lords. The most common origin of American and English towns is the primitive agricultural village or coalescence of several villages, and since facilities for trade were the primary cause of the development of village communities into towns, it follows that those villages which were situated at fording places in the midst of a fertile plain or on good trade routes would be favored in growth."

The dominant factor in the development from trade is that its location is where there must be a break in the transportation. This requires the plant for the work; the men to carry it on, facilities for storage, in short, the whole complex mechanism of exchange. And, further, side by side with these several institutions is the plant of the trader and dealer in commodities exchanged, and side by side with them, the other institutions necessary to support those engaged in the traffic. It is interesting to note that the great cities of the country are by the shore where extensive machinery of transfer is necessary and where the type of the vehicle employed is radically changed. Every great city owes its eminence to commerce between the railways on the one hand and shipping on the other. In the United States all but two of the cities with more than 100,000 population in 1890 were on navigable waters. Some writers, through the close connection between transportation facilities and the urban conditions, see commerce the sole agent in determining the distribution of population and its concentration in cities; but this is probably but one of the causes prominently involved.

2. *Manufactures.*—A second cause the engineer must reckon is that of manufactures. The development of manufactures is dependent upon the production of power, and the stability of manufacturing industry is therefore co-equal with that of the power obtainable. Natural power—water, gas, wind—are each invaluable in their own

way, but subject to variation not always easy to reckon with. From the engineering standpoint their stability and permanency are the first considerations. Industries inevitably group themselves about natural power, utilizing it to its limit, and even surpassing the natural supply. The city of Holyoke, Mass., is a conspicuous example of where the large water power is supplemented already by steam, and many plants are operated solely by that power. Permanency is established in those localities where railway and water meet. As for example, in Cleveland where the coal meets the ore transported by the cheap water carriage. Population inevitably gravitates toward such centers, such population including both those directly engaged in the manufacturng industries and those supplying their varying needs. But the tendency is not wholly in one direction. A decentralization in many localities is marked, manufacturers being compelled to remove their business from centers to adjoining suburban smaller cities and towns to escape the exactions of high rents and costs and yet be in position to avail themselves of the superior shipping facilities. As an example of this tendency, it is noted that in 1885, there were 65 iron foundries in New York City, only fifteen of which were remaining in 1899. Some had gone out of business, but the greater portion had removed to more satisfactory localities in neighboring towns along the Hudson River or in New Jersey.

Such conditions complicate the problem of the engineer; he must provide for the wants of the community. Manufactures mean increased population, and it calls for the exercise of the most accurate judgment to pass confidently on their nature, development, stability, permanency, transportation facilities, possibility of removal, the development of suburban centers which may or may not become parts of a central service, and adjust them to such a basis that moneys will not be squandered on the one hand, nor that the works established must not be rebult or parrelleled within the same generation. Especially trying is this in small cities which do not give promise of extraordinary development within any moderate period; such a place, for example, as our own city of Beloit, where inside real property has increased ten fold within twenty years. The experience of every engineer will furnish illustration of small cities suddenly grown large with inadequate facilities for all works of a public nature, and where the people of the present day are paying dearly for the errors in judgment of those of an earlier period.

3. *Social*—The third cause is purely the social one. Man is by nature a gregarious animal; he loves company and good fellowship. This is, I believe, the real basis of the drift from the farms to the cities; the quiet and isolation of the farmer's life is distasteful to most men; the miner submts to self-denial in the hope of sudden gain in wealth with which to pass his later days with his kind; the sailor plunges in all manner of excesses of the city; all these are at foundation one and the same,—the desire of association with others. All the attractions of city life are spread in the literature of the day which, thanks to the ease of transportation, is sent to the most remote corners of the

earth. Men come to know more about the life outside their own little horizon and become restless to share in other more attractive callings in life. In the country it is quiet, with few pleasures or opportunities which the present day terms the necessities of life; but in the cities there is the hurry and excitement, the stir and push of business; there are the amusements of every sort, the opera, the theater, the resort of every grade, where men congregate and pass away the time in congenial companionship. In the city also are the great educational institutions, the museums, and the art collections, each making its appeal to the different types of men. There is the higher standard of living, the comforts and luxuries every man enjoys. All these are positive influences drawing away from the country life to the city. I will admit that any extended discussion of this phase of the question is out of place in this paper, but the engineer is bound not to lose sight of this most important factor in any estimate he is making of the character and permanency of any given community. Especially is this true where, as is so often the case with public utilities, he is called upon to provide for communities in which the social and esthetic features are the principal factors in determining conditions. The engineering problem involved in such a strictly university town as Ann Arbor, for example, involves elements of growth and stability as real and permanent, if not as extensive, as its neighbor, Detroit.

It would carry us far beyond the purposes of this paper to further analyze the causes tending to the concentration of population in the cities, but the three above given are, it seems to me, sufficently comprehensive to include what is essential to this discussion. What might be added would be either an elaboration of these general propositions, or minor considerations under them. They indicate clearly the elements tending to centralization, and the conditions of permanency to be expected. It is not plain that they are all equally significant in any particular locality, but each is to be taken for its value in fixing the conditions of procedure. He is a wise engineer who proceeds in a large way to the study of the problem in hand, and who takes into consideration not what the present day requires, but who can look ahead and form some intelligent opinion of what the future will probably demand. It is the most difficult feature of any problem generally, but one upon which the ultimate satisfactory solution depends.

## EFFECTS OF CONCENTRATION OF POPULATION UPON ENGINEERING PROBLEMS

Turning to some direct effects of concentration, the causes and probable permanency we have endeavored to make clear above, it should be noted at the outset that we can hardly expect to extend the discussion to all branches of the profession. The demands of the modern city with its intricate needs upon the engineer, reach to the division of lines of study and research of the profession itself.

Water, sewerage, transportation, pavements, roads, bridges, parks, boulevards, heating, lighting, buildings, foundations, and means of communication, in fact all public works and private enterprises of any magnitude, enlist his services. The application in any particular branch will be suggested to those of you having to do with such specialized work. I shall therefore restrict my further discussion to those two lines with which I am personally the most familiar, viz., water supply and sewerage disposal.

1. *The Result of Large Numbers.*—The most conspicuous example of the difficulties caused by large numbers is with the water *supply of New York City. Prof. Zeublin has summed up in a few well stated sentences the history of the New York water supply, which I venture to introduce.

> "In 1832 New York City instituted measures to secure the Croton watershed. The Croton aqueduct which was subsequently built carried the water a distance of forty miles and, up to 1884, had involved the city in an expense for construction of $37,000,000, providing for a supply of ninety million gallons of water daily......In 1885 it was necessary to start the building of a new aqueduct which began to supply the city in 1890, and has a maximum capacity of 290,000,000 gallons daily, involving an expense of $24,000,000. This larger supply is brought to Manhattan in a 14-ft. tunnel at an average depth of 150 ft., passing under the Harlem River at a depth of 300 ft. below the river bed. Since 1890 another budget of $24,000,000 has been necessary to provide extensions and reservoirs. A dam is being constructed 1350 ft. long, and 227 ft. high......Manhattan has had an excellent supply of water from the Croton and subsidiary systems; the only difficulty has been the rapid growth of population necessitating continual extensions, which is now further complicated by the need for supplying Greater New York, the other boroughs being less favorably situated than Manhattan. Brooklyn has a very imperfect supply from Long Island and has reached the limit of its powers, which had been severely restricted through the opposition of rural legislators.
>
> "In order to take advantage of New York's necessities, the Ramapo Water Company secured control of large watersheds in New York and New Jersey in the natural region for New York's next extension. On August 6, 1899, the Commissioner of Water Supply, Mr. William Dalton, presented to the Board of Public Improvements a proposed contract with the city and the Ramapo Water Company. This contract would have involved the city in the payment of $70 per 1,000,000 gallons of water for a period of forty years, as well as the necessity of buying what it needed from this Company to the amount of 200,000,000 gallons per diem. A majority of the members present at the Board meeting inform-

* American Municipal Progres, Charles Zeublin, MacMillan & Co., 1903.

ally indicated their approval of the contract. The knowledge of this action aroused Comptroller Coler and many citizens of New York notably the members of the Merchants' Association......The Merchants' Association undertook an investigation of the water supply of New York, which has proved to be one of the most valuable ever carried through by a private body in this country. They examined the history of New York's water supply; the various possibilities of increase through private and public sources; the possible uses of water; the question of waste; salt water for fire protection; street washing and sewer cleansing; the legal relations involved; and finally the immense advantage of municipal ownership as contrasted with any other method."

This elaborate investigation by the Merchants' Association was spread over quite a period and called into its service some of the most competent Eastern engineers, with the result that recently a scheme to take water from the Catskill Mountains has been recommended and adopted, and works to cost $160,000,000 have been projected, if not actually commenced at this writing.

The striking features of this brief history of New York's water supply are the tremendous scale of each of the successive enterprises, the great cost involved and the rapid inadequacy of each project in turn. Reference will be made later to the care exercised in protection of water supplies. But it will be noted that with a great supply like that of New York, extraordinary provisions must be made to protect the supply of a great population from the pollutions of smaller growing populations. Some years ago the writer had occasion to inspect the Croton watershed, and in conversation, the Superintendent informed him, that he had already burned the entire set of buildings of 160 farms, which had been acquired solely to prevent possible pollutions to the Croton River. Such action seems harsh at first glance, but is one of the necessities we sometimes practice.

The experiences of New York have been repeated in many of the large cities of this country within the last ten years. The increasing populations, with their greater stability and permanency, have made demands which must be met as rapidly as possible. The public is aroused to the matter of plenty of good wholesome water, and the service must be adequate to its demands. It is necessary but to mention the immense projected works of the Metropolitan Board of Boston, the improvements at Philadelphia, Washington, Albany, Buffalo, Cleveland, Chicago, Indianapolis, Pittsburg, Allegheny, Cincinnati, Louisville, St. Louis, New Orleans, and Denver, now completed or under way, or to be put under immediate contract, to show the great demands the large centers make upon the engineer. The difficulties are the same New York met with—the great skill necessary in projecting and carrying through such vast enterprises, the expense involved, and above all to make them on a scale adapted to the probable advances of the coming years.

2. *The Disposal of Wastes of Large Populations.*—A second problem the urban population thrusts on the engineer, is the cheap, safe, and efficient disposal of its wastes. The disposal of the sewage from the city of Boston is one of the best I can cite by way of illustration. From 1709 on, various enactments have been made controlling the drainage of that city. In 1837 the first superintendent of sewers was appointed, his office being to control as satisfactorily as possible, the various drains and cess-pools which as late as 1875 were still in use in that city. In 1875 the First Boston Sewerage Commission was appointed, and the 125 miles of sewers which emptied directly into the bay were, under its direction, united to a central sewer with its discharge on Moon Island. More than $5,000,000 were spent by this Commission during the next ten years in establishing the well-known system on the Island. Later legislation has been enacted empowering the Boston authorities to co-operate with the Metropolitan Sewerage Commissioners, with the result that now 22 towns and cities in the Metropolitan District combine to discharge their sewage into tide water through two separate outlets, one on Moon Island and the other on Deer Island.

The favorite method of disposal of sewage has been by means of water carriage; it is the simplest and, as we will show later, not necessarily to be condemned when properly conducted. The problems the sewage of the growing population, force on the engineer, are among the most serious to settle; the case of Boston already cited is to the point. But the modern engineer working under the demands of the larger and growing city of today has to meet a different proposition from his brother of the last generation. There are systems of sewage disposal to be considered other than dumping the raw sewage into the nearest neighboring stream. He may be called upon to deliver the sewage from a growing population into a stream in a purified condition, or sufficiently so to prevent a nuisance, and hence filtraton of the sewage follows, as at Brockton, Mass., or at South Framingham, or chemical precipitation of the dissolved and suspended materials as at Worcester, Mass., or the use of the micro-organisms as in the septic tank method, so successfully used by Mr Alvord of this city. I am not aware that sewage farming successfully applied in Berlin and other foreign cities has as yet been introduced into American practice, other than the sewage farm at Pasadena, California.

The sewerage problem is all the more difficult as it does not, as do water and other utilities, yield direct returns to the people. Its return is in the form of better health and greater comfort and safety to the community. It is a part of the problem of how to keep clean homes, and cleanliness is the primal element in all good living.

3. *The Supply of Water to Large Populations.*—The supply of good wholesome water is one of the most important problems the urban conditions present to the engineer. Nor is it easy to determine just what shall be done in any particular case. The sources of the supply; the freedom of the same from pollution present or

From the *Bulletin* of the Department of Health, City of Chicago, Vol. IX, No. 8, 1906.

## VITAL STATISTICS OF THE TEN LARGEST AMERICAN CITIES.

(As per Population, U. S. Census, 1900.)

| | New York | Chicago | Philadelphia | St. Louis | Boston | Baltimore | Cleveland | San Francisco | Buffalo | New Orleans |
|---|---|---|---|---|---|---|---|---|---|---|
| Population, 1900 ....... | 3 446 042 | 1 698 575 | 1 293 697 | 575 200 | 560 892 | 541 000 | 395 000 | 360 000 | 352 387 | 300 000 |
| " 1905........ | 4 024 780 | 1 990 750 | 1 438 318 | 685 000 | 595 380 | 550 000 | 440 000 | 475 000 | 400 000 | 333 000 |
| Total deaths, 1905 ....... | 73 714 | 27 212 | 24 807 | 10 342 | 11 007 | 10 695 | 6 424 | 7 290 | 5 656 | 7 329 |
| Rate per 1000, 1905........ | 18 32 | 13.67 | 17.25 | 15.09 | 18.49 | 18.77 | 14.60 | 15.34 | 14.14 | 22.01 |
| Average annual rate, 1901-5. | 18 95 | 14.24 | 18.08 | 16.71 | 18.80 | 18.93 | 15.23 | 17.71 | 14.36 | 21.32 |

### Typhoid Fever.

| | New York | Chicago | Philadelphia | St. Louis | Boston | Baltimore | Cleveland | San Francisco | Buffalo | New Orleans |
|---|---|---|---|---|---|---|---|---|---|---|
| Total deaths, 1905 ....... | 649 | 329 | 689 | .127 | 117 | 197 | 67 | 94 | 90 | 101 |
| Rate per 10 000, 1905 ....... | 1.61 | 1.65 | 4.79 | 1.85 | 2.13 | 3.58 | 1.52 | 1.98 | 2 27 | 3.03 |
| Average annual rate, 1901-5. | 1.87 | 2.66 | 4.70 | 3 25 | 2.32 | 3.52 | 4 93 | 2.94 | 2.77 | 3.83 |

An improved water supply, to the betterment of which the Department has devoted daily study and effort since 1895, has put typhoid fever in the list of vanishing diseases. In 1891 Chicago had the highest typhoid death rate—173 per 100 000—of any city in the civilized world. Last year this rate was 16 in the 100 000—a reduction of more than 90 per cent from the '91 rate, and among the lowest of American cities.

possible; the permanency of the supply; and the gauging the plans of the works to meet the city's development, are among the difficulties many of you have met with. Were the conditions of the city life fixed, were there no changes in population, were there no extensions or additions to the city, then the problem would not be a difficult one to solve. But when we remember the fluctuations in numbers and types of people, the increase in number and kind of manufactures, the encroachments of neighboring communities, etc., then the problem becomes exceedingly complicated. The first difficulty a growing city presents is with the sources of the supply. The amount of water available may be adequate for limited populations, but in how many cases are we called upon to suggest how these sources may be extended without prejudice to the demands of the city. The extension of the city may also reach to the territory of the supply itself, and thus endanger the lives and the health of the citizens. In how many cases does the increase in the chlorine content of the waters, and the amounts of the nitrates, show that the supply is receiving increasing amounts of the waste of the city which seeps into the under currents of the water from whence the supply is drawn. It is well for many a community we might mention, that the methods of nature's great laboratory are at work converting these wastes into harmless forms before consumption, whatever we may say or think of the esthetics of the suggestion! The demands of the modern city, require the efficient purification of the water supplies and a quality not dreamed of in the last generation. Hence come the filtering and purifying systems and the great engineering works in connection with them. The problems the modern city thrusts at the engineer, for the disposal of the wastes of other cities near at hand, are among the most trying he is called upon to adjust. The prevalent practice of using the nearest water course for the disposal of the city's sewage is one which the near future will, I am sure, measurably do away with, but for the present the problem of the water supply will be one of *efficient purification.* The cities will have good water at any cost, and the engineer of the future must be equipped to grapple with the problem of the cheapest and most efficient solution. Take the Mississippi river as an example. At the present time there are 25 water systems drawing their supply directly from the river; in 13 of these there is some system of filtration used, in 12 there is none, the water being supplied to the commnuities in its natural condition. The population using the filtered water is 226,471; the population using unfiltered water 1,162,-614; that is, only about one in six of the population thus supplied having a system of purification of the water; and that, in the face of the fact that all of the cities on the stream empty their sewers directly into the river, the population on the river and its tributaries being upwards of 6,000,000. Any one who has seen the water of the Mississippi River in its natural condition knows what the character of the water is, and that the silt and solids transported by the river render it unfit for use, to say nothing of the waste and sewage from

so vast a population. It is greatly to the credit of those operating the water works on the Mississippi River that efficient purification plants have been installed at so many points already, and that the agitation of the pure water question has stimulated most of the others to investigate the question to see what can be done to better their condition.

It is unnecessary to dwell on a phase of the question with which all are more or less familiar, and it must be patent to all that there have been no problems of more significance to the well-being of the community than those the changing conditions of urban life have offered to the engineer, in the adjustment of its water supply and sewage disposal.

4. *The Chicago Drainage System.*—This paper would not be complete without special mention of the most remarkable sanitary system in the country, if not in the world,—that of Chicago. This, however, has been presented to this society by those more competent than I to speak concerning it, so that it will be passed over except merely to recall the fact that here we meet with the most remarkable combination of extension of the water supply to prevent sewage pollution, and the establishment of a system for the efficient removal of the sewage and waste materials. One has but to recall the history of Chicago from 1834, when the sum of $95.50 was appropriated for digging a public well, the first public water supply in this city, through the use of pipes and then intakes and tunnels, until the distance of four miles into the lake has been reached, to get beyond pollution from the sewage of the city; and with that combine the study of the systems of sewers, each proving inadequate until the drainage canal, sometimes properly called the eighth wonder of the world, sent the sewage of the city away from the city to the southwest. The success of this work is now a matter of history and, fully established, will remain to benefit this city for succeeding generations. All this is well known to you and will not be expanded at this time; it would, however, be unfortunate not to utilize this, the most conspicuous example, to illustrate the relation of protection of a water supply, and how efficiently nature will remove effete matters if given the opportunity.

5. *The Results of Education in Larger Cities.*—Another way in which the great centers of population affect the problems of the engineer is not so obvious but will well be worth our serious consideration. I refer to that influence steadily at work among larger populations tending towards the elevation of the standards of living. With the urban tendencies come wealth, and with wealth come better conditions of living. In the cities are the museums and the art galleries; here are the lectures and public schools; here are the libraries, and the colleges and the great universities; here are the technical schools and the engineering societies; here are the fairs and the great exhibitions of the arts and the sciences. I would not be misunderstood on this point: there are strong schools and colleges and universities in our smaller towns

and cities, but the great schools for research in this country and abroad are in or under the direct influence of the cities; and from these universities there come constantly influences profoundly modifying the work of the engineer. The people are becoming more enlightened and demand more for themselves. The water supply "good enough" for yesterday will not be tolerated today; the plumbing of ten years ago is thrown into the scrap-heap; the call is for better homes; better facilities for transportation; better food; more comfort to living. And all these the engineer of to-morrow must furnish. As Mr. Justice Holmes wrote in that famous decision in the Drainage Canal suit:

> "At the outset we cannot but be struck by the consideration that if this suit had been brought fifty years ago it almost necessarily would have failed. There is no pretense that there is a nuisance of the simple kind that was known to the older common law."

The conditions of living are changing and that change is primarily due to the influences of the city.

6. *The Ethical Effect of Populations.*—The last effect of populations upon the problems of the engineer I will note is the purely ethical one. The congestion of population in centers has placed upon those charged with the betterment of conditions, the responsibility of relieving them from the evils which such centralization brings upon itself. The ancient city struggled with the evils of its centered population and devised public works to mitigate them; the great Roman aqueducts, remnants of which may be seen to this day stalking across the Roman Campagna, were the result of the demand of the Roman peoples for wholesome water. But the cities of the middle ages were notorious for the unsanitary conditions under which the people existed; the history of the plagues and disasters which overwhelmed them is familiar to you all; it was not until these were stayed that the steady drift to the cities set in and the centralization of populations was assured. Not until the beginning of the 19th century did the birth rate of London exceed its death rate and the rapid growth of that metropolis become assured. The greatest work of the engineer lies along the lines which deal with human life; and the reward is not always in the largest financial return, but in the inestimable service rendered to his fellow men. The city gathers with its growth the objectionable elements of human living; it is the inestimable privilege of the engineer to be the instrument through whom these may be ameliorated or removed; he may well congratulate himself that herein lies the opportunity given to few men or callings. I will not detain you to speak of the relation of engineering works to the prevention or spread of disease. Take a single illustration: you are all familiar with the great Cholera epidemic in Hamburg, Germany, in 1892, when the total number of Cholera cases was 17,020 with a death list of 8,605, while Altona, separated

from Hamburg only by an imaginary line along one of the streets and with one fourth of its population, had but 328 deaths; in the words of Dr. Koch "Cholera in Hamburg went right up to the boundary of Altona and there stopped." The reason was simply that Altona had a good efficiently filtered water supply and Hamburg had not; Altona was spared through the timely services of the engineer.

The efforts made in our own country to ward off the spread of typhoid fever are most commendable, and they enlist in every case the services of the engineer. The last census showed that in the United States there were 48 cities with a death rate from typhoid fever of more than 40 per 10,000, and a glance at a map will show that in almost every case these cities were on the bank of some river from which they took their water supply. To lessen the spread of this water-borne disease has been the untiring effort of some of our most gifted engineers, and the great sums already expended and projected for works to purify the water supply of these, attest the value of their efforts. We might profitably pass the hour in studying the methods employed and results obtained; it must suffice to merely use one illustration of the decrease of this dreadful disease.

The most striking example however of the significance and value of sanitary science is that offered by the Health department of this city, and detailed in the series of bulletins issued since the opening of this year. These data (and there is no reason to question their reliability) demonstrate that since 1869 the average age of death in this city has doubled. Nor is this remarkable statement possible

TABLE "A"

INCREASING DURATION OF LIFE IN CHICAGO DOUBLED IN A SINGLE GENERATION.

Average Age of Decedents in the Years

1875—16 years, 2 months, 12 days.

1885—20 years, 4 months, 26 days.

1895—24 years, 7 months, 9 days.

1905—31 years, 10 months, 1 day,

While only 3.7 per cent of those who died in 1875 had reached the age of three-score years, last year 19.6 per cent of the decedents were 60 years old or over, and 10.1 per cent had lived beyond the scriptural limit of "three-score years and ten."

There were 882 deaths among those over 80 years of age, or 3.2 per cent of the total—nearly as large a proportion of octogenarians in 1905 as of sexagenarians in 1875.

because of any forced conditions in the two years of 1869 and 1905, for if the average annual rate per 1000 of populaton be compared by decades, there is shown a constant gradual decrease from 23.82 per 1,000 in 1875, to 14.71 per 1,000 in 1905. Whatever may be the adequate explanation of this wonderful result, with all due praise

TABLE "B"

DECREASING MORTALITY IN CHICAGO, BY DECADES, ENDED 1905.

Average Annual Rates per 1000 of Population,

| Decades: | Rates: |
|---|---|
| 1866–1875. | 23.86 |
| 1876–1885. | 20.30 |
| 1886–1895. | 20.09 |
| 1896–1905. | 14.71 |

The decrease from 23.82 per 1000 in the decade 1866-1875 to 14.71 per 1000 in the decade ended last year is 38.2 per cent.

for the beneficence of preventive medicine which has done so much to alleviate disease and drive back the dread terror, let us remember that the engineer has contributed his full share to bringing about the results; that, as Dr. Whalen rightly says:

> "It is chiefly sanitation which has involved an expenditure of upwards of $100,000,000 in securing and distributing a pure water supply, and of a still larger sum in the aggregate, for lifting Chicago's feet out of the original mud and mire; for raising the city's datum so as to secure drainage; for the construction and maintenance of a sewerage system; for the main drainage channel and sanitary water-way; for a magnificent park and open-air space system; or free bathing facilities, and for many other works of sanitation unrivalled."

And what has been Chicago's history has been the history of every city, where the intelligence of the engineer has been called to the service of the public. In 1891 the city of Lawrence, Massachusetts, introduced and put in operation a filtration system to purify its water supply because of the conditions which had grown intolerable. Ten years later Mr. Hiram F. Mills, under whose direction the filtration plant was installed presented some results of the operation of the plant through that period and in the course of his paper called attention to the fact that not only had the death rate from typhoid fever been reduced since the installation of the filter system, but that the whole tendency of the death rate for the city had been changed.

Is such service not worth while, and do not the problems of the city of the future offer returns, each in its own kind, that is worthy the most strenuous effort of every engineer?

DISCUSSION.

*Mr. Ernest McCullough:* I agree with pretty nearly everything that has been said by the speaker this evening, except the last tables showing the death rate in Chicago. I think the railroad companies are entitled to some credit for the decrease in the death rate in this city during later years. From 1866 to 1875, Chicago

had just commenced to enter upon a period of growth, and a large proportion of those who died then were natives of Chicago. A large proportion of those who die today are foreign born, and many of them are the parents of immigrants, which will largely account for the increased age. As to the low death rate, of course a great deal can be credited to the extension of the drainage canal, and the extension out into the lake of the intakes to get pure water. But people have a habit now of dying away from home. In the earlier days the railroad transportation was not so good, and the passenger rates were very high, so that people who were in bad health and were not well-to-do, had to remain at home. But in these prosperous times, everyone who can acord it, or who feels the need of a change of climate, goes away, to California or some other state, and often these people die while on the trip, which undoubtedly increases the death rate in those states. This showing is a source of regret to the people who live there. I do not think the saitarians ought to take all the credit for the decrease in death rate, but I think they can claim much credit for a decrease in typhoid fever. So, for the increase of average age of the population and decrease in average death rate, we should give some credit to the transportation departments of the railroad companies, as well as to the sanitarians.

*Mr. W. L. Abbott:* There are engineering problems, such as we ordinarily understand them, which consist in designing and in construction to obtain certain definite results which are determined beforehand. There is another kind of engineering of a higher nature, which consists in estimating and predicting what the requirements of the distant future will be. Anyone who undertakes this kind of prophecy must have great courage; he will either be ridiculed by his contemporaries for his visionary ideas, or ridiculed by those who come later for his short-sightedness. The work indicated by Prof. Smith tonight is of this latter kind and what, both for the judgment required and for its ultimate benefits to mankind, may be truly classed as of the highest character. I was impressed by the fact, while listening to the presentation of this paper showing the difficulties experienced by other cities in obtaining a satisfactory and wholesome water supply, and also the difficulties met with in disposing of their sewage, how fortunate the city of Chicago is, in these two respects. I think it may be safely stated that there is not another city, large or small, on the face of the earth so well situated as the city of Chicago, both for obtaining an abundant and wholesome supply of water and an easy back-door place for the disposition of slops. It is not to be wondered at that the city of St. Louis should at once set up the complaint that its water supply is being polluted, and if it had been the city of Chicago located lower down the stream from, say, the city of Milwaukee, there is no doubt but we would have made as big a complaint as St. Louis, and we would have been very loath to admit, even after it had been proved

to us, that we were being benefited by the city further up the stream.

*Mr. Saner:* In regard to the population curve of St. Louis. In what way was that increase to 1950 figured? There must have been some equation used to figure that curve, and it looks to me as if it were a compound curve.

*Prof. Smith:* That was a chart taken from one of the reports of the Engineering Department to the Board of Public Works, about 1900 or 1901. I had this chart made a year ago for another purpose, but I suppose that the production of these curves is a matter of speculation, basing them upon the points represented by the intersection of the years and of the population. Of course we always have the absolute figures of the United States census reports, and we all know how our pride suffers, as the numbers often fall under what our "school census" shows, so that the data has an element of unreliablity except so far as the United States census is concerned.

*Mr. Saner:* My work recently has been along the line of estimating how soon all the Loop District will be occupied by skyscrapers. Of course we can readily understand that there are a good many difficulties. We cannot tell how many panics we are going to have in the next few years, but I have looked up the records of all the buildings and have all the records back as far as 1890. The growth seems to be fairly regular from 1896 to 1906, and I have figured out the compound rate during those ten years, and platted that on ahead. I would like to have an opinion, if possible, on how near that is right, using a compound rate. It figures out 34 years; that is, in 1930 the down-town district will be covered by buildings of over nine stories. But there has been a good deal of discussion since making up this curve as to whether that compound rate is right. The curve increases very fast in the latter half.

*Dr. R. S. Moss:* There is one thing I would like to speak about, and that is, Prof. Smith stated that the Illinois river at a certain point between here and St. Louis purified itself twice. I would like to ask what is the rate of purification; that is to say, if it has been determined, what amount of oxygen is required to purify a given amount of nitrogen, and is that determined on a given volume of water? If so, then we can reach a limit in a given number of years where it would be dangerous to pass more than a given amount of sewage.

*Prof. Smith:* The answer to that question is rather difficult. We would not measure the degree of purification by the oxygen consumption. The term "purity" or "impurity" is merely a relative term. I said that I considered the Illinois river purified so far as the Chicago river was concerned, when it had reached the normal condition of the water. Of course the Mississippi river water is never fit to use in its natural condition. It must be subjected to a system of artifical purification before using; therefore, the use of the term "purity" is a relative one. The expression "purified itself

twice" was true in the sense that at Averyville, 157 miles below Lockport, the water has come, both in chemical character and in bacterial content, to compare with the normal water for that section. The sewage element is quite effectually destroyed. For instance, the study of a large number of samples taken from the Drainage Canal show the presence of, I think, about 3,000,000 bacteria per cubic centimeter. Of this number, upwards of 100,000 were the distinct sewage form, or its allied forms. When Averyville was reached the number contained in the river had, according to this chart, passed on an average below 5,000, and the sewage forms had diminished so that only 60 per cent. of the samples revealed the presence of the colon forms. Hence we say that the river has purified itself so far as the sewage is concerned.

*Mr. McCullough:* In regard to the sewage and matters that are held in suspension and not in solution; this will gradually settle in the channel it flows down. What effect would that have on the purity of the water?

*Prof. Smith:* It would gradually disappear, owing to the fact that the sediment contained in the stream is a purifying agent, so that the particles of sediment tend to ball together, and therefore their gravity becomes greater than that of the water, and they settle and carry with them the organisms and matter in solution. When it reaches the bed of the river, the ordinary purifying agencies are at work, by which the matter is converted into nitric acid. A study of these analyses shows a continual decrease of nitrates as you pass down the river, showing that the material has been precipitated to the bottom of the river, where it comes in contact with the purifying agencies.

*Mr. DeWolfe:* Then the Illinois River acts as a permanent and indefinite purifying influence?

*Prof. Smith:* For any reasonable time, I think. The natural agencies in that stream tend to the purification of the stream.

*Mr. DeWolfe:* It is rather a matter of distance than quantity?

*Prof. Smith:* As far as we can judge the self-purifying influence of the Illinois river will be ample to care for the present sewage and a considerable increased amount.

*Mr. Abbott:* What effect on the purification does a water fall have, such as at the Bear Trap dam?

*Prof. Smith:* Very little. The oxidizing effect of the air upon water I think has been greatly overestimated. It helps somewhat, but the effect very soon disappears.

*Mr. Abbott:* Flowing quietly in a stream will have nearly the same purifying effect as when agitated?

*Prof. Smith:* Yes, I think so.

*Dr. Moss:* I would like to ask this question,—if it is not due to the air present in the water, how do we get the nitrogen converted into nitrates?

*Prof. Smith:* Oxygen is constantly taken up by the water, but it

is not the oxidizing process as we use the term generally. It is an oxidizing process which takes place through the agency of micro-organisms.

*Mr. Burdick:* Reference has been made to the population curve of St. Louis, which is apparently concave toward the left of the diagram. This curve, if extended indefinitely at the same rate, will of course, give an infinite increase in population, and, as Prof. Smith has pointed out, in the long run the tendency of that curve is in the other direction. That is, the per cent. of growth is greater in the earlier years and smaller in the later years, and I think any curve that is concave toward the right of the diagram should be used with considerable caution, and certainly future requirements should not be based upon such a curve as that, especially one based on only a few years' data. I believe there is no better way of forecasting the future than by records of the past.

*Mr. McCullough:* I think that St. Louis curve was drawn with a French curve. They took the figures for New York and Chicago, and it was a matter of local pride in St. Louis that the curve in a few years would parallel the curve of Chicago and New York.

*Mr. McMeen:* With reference to cities and their population, a comparison of a large number of diagrams of the growth of cities in the United States for a period from 1820 to 1900, shows curves of substantially the same shape as St. Louis. As I recall it, the curves to which I refer include all cities in the Unted States having in 1820 a population of over 5,000. They are all concave on the left, wth few exceptions. All the curves but one show the same continual increase from census to census. They have various peculiarities, so that as sorted out, one gets distributions which are relative to Mason and Dixon's line;—differences of degree, whether or not of actual shape. The curves of the southern states are mainly flat; of the northern states more nearly vertical; and practically all concave on the left.

I have had some little experience in forecasting what shall be future conditions of telephony, by noting urban tendencies, and have taken some care in comparing forecasts thus made, with the actual conditions of cities at later times, hoping and attempting thereby to learn how much might be invested and how to dispose of an investment in that peculiar kind of work, as very large sums of money were to be expended on some basis of prophecy. The instance cited as to Rockford's forecast is, it would seem, a fair sample of not hitting very close. The guess usually is closer than that, so that one may say it is quite possible to forecast what will be true of urban tendencies of growth in general. The whole basis of the art of which I speak lies in this ability to forecast population, not alone in gross amount, but to say in a given community what will be the character, and, perhaps, what will be the wealth of a given portion of population. This element is of a general sociological order,—to find out all that may be possible about the people who are going to live in a certain region and in every way

possible to know what their general activity will be at a given future time.

*Mr. Robinson:* How far from Peoria is Averyville?

*Prof. Smith:* The point below Peoria where the river purifies itself is Campsville.

*Mr. Robinson:* In your study did you determine any given distance that the Illinois river will purify itself?

*Prof. Smith:* At Campsville, some distance above Grafton, purification begins immediately, and at 90 miles it is about complete. Purification is complete at Averyville.

*Mr. Burdick:* What is your idea of the effect of the dilution of the sewage of the city of Chicago?

*Prof. Smith:* The effect of dilution is to diminish the chances of infection; to prolong the life of sewage organism; to push sewage further down stream and increase the rate of flow; increasing the rate of flow prevents sedimentation. So purification takes place after the stream has run to a distance.

*Mr. Burdick:* The law requires that dilution shall be about 9 to 1. The question in my mind was as to whether the investigations of the biologists in this canal case had tended to substantiate the correctness of that procedure, or whether the opposite had been the case.

*Prof. Smith:* The dilution will tend to push the zone of purification further down the stream, but there is abundant distance to purify itself, and the river is of sufficient length to allow purification.

*Mr. Abbott:* Is that due to the increased velocity of the river?

*Prof. Smith:* The tendency is to diminish sedimentation and to push the zone of purification further down the stream.

# A NEW METHOD OF CALCULATING BRIDGE STRESSES BY MEANS OF END-SHEARS

W. T. CURTIS, M. W. S. E.

*Presented Friday, March 23, 1906.*

Two years ago, in the March issue of the Journal, Mr. Gibson presented a table of End Shears. Since that time he has perfected and enlarged the table to the form now shown on the accompanying sheets, and believing the results of Mr. Gibson's efforts to be highly worthy of consideration, the writer ventures to discuss the table in its new form, and at the same time commends it as a practical aid to those directly interested in the calculation of stresses in railroad bridges.

The determination of stresses in bridges by means of assumed wheel loads is the recognized method of calculation. The arithmetical work involved by this process is, however, tedious and expensive, and it is the purpose of this new table to eliminate the laborious features and to substitute a concise method, but comprehensive and accurate.

A brief explanation of this table will not only enable the engineer to use it readily, but should be sufficient to enable him to take it up for practical application at a future time, without re-study. This, in the writer's estimation, is one of the salient virtues of the table. We already have many calculation schemes which are so involved as to require much re-study at each successive application.

This particular table is figured for Cooper's E-50 loading. Heavier or lighter engines of the same type can be handled by this table by direct proportion of results. For other types of loadings a new table would have to be prepared, but as there is a tendency among engineers towards uniformity of specifications for loading, it is hoped that occasion will not arise for a multitude of tables, as the labor involved in compiling a table is considerable.

Only a condensed copy of the table is here presented, covering lengths at 10 ft. intervals. Blue prints of the unabridged table, covering variations of one foot in length up to 70 ft., two feet to 200 ft., and ten feet up to 300 ft., may be had of the Secretary for a charge to cover cost of printing and postage.

The shear table proper, as appears under the wheel diagram, reads in either direction from any wheel for spans from 10 ft. to 300 ft. lengths being indicated in column headed "L" at the left.

The figures in column A are the right-hand end-shears delivered from the engine so placed that the wheel at the head of the column is directly over the right hand end of the span (the span itself ex-

tending to the left). Similarly, the figures in column B show the left hand end-shears when the wheel at the head of the column is placed directly over the left support of the span extending to the right. These shears *do not include the wheel at the point considered.*

The shears occurring simultaneously with the maximum abutment reactions, are indicated by a heavy line immediately over the figures. This maximum shear occurs when the wheel at the head of the vertical column is placed at the point of support. This feature gives a direct reading of maximum end-shear.

The abutment reaction is found by adding the wheel load at the point of support to the end shear. The greatest abutment reaction, therefore, occurs when we have the greatest shear, and the table is thus direct-reading for both.

In girders without panels the end-shear is the same for all practical purposes as the abutment reaction, for when the wheel producing this reaction is moved slightly off the abutment towards the center of the span, the shear is only slightly less than the original abutment reaction, decreasing in amount from this abutment-reaction as the distance of the wheel from the abutment becomes greater.

To repeat our definitions:

*Shear* is understood to mean the reaction at a support of a single span, *less* the weight of the wheel immediately over that support.

*Abutment reaction* is the total reaction at a support of a single span, and is determined by adding to the shear the weight of the wheel immediately over the abutment considered.

*Pier reaction,* therefore, means the reaction from two spans supported at a common point, and is found by adding to the sum of shears A and B for the proper lengths (and for the same position of loading) the weight of the wheel immediately over the point in question. It is readily seen that this also takes care of panel concentration.

Mr. Gibson's table differs from other similar calculation schemes in four main features:

1st. It gives the end-shears separately for any length of span, with any wheel over the abutment, and for the span extending in either direction from that wheel. It, moreover, directly indicates the maximum.

2nd. It designates the wheel under which will be found the maximum pier-reaction for any two equal or unequal spans, and determines the reaction.

3rd. It gives the shears occurring simultaneously at the opposite ends of a span.

4th. It gives the exact location of engine and train load for maximum pier-reaction, where the span is so long that the maximum reaction occurs under the uniform load.

Other tables give maximum shears only, without designating the

# COOPER'S E 50 ENGINE.

This table locates maximum reaction, moments and shears, and gives short methods for determining the same. Shears are shown in thousands of pounds for one rail.

—Josiah Gibson, C.E.—

Wheels 1 to 18; spacings 8' 5' 5' 5' 9' 5' 6' 5' 8' 8' 5' 5' 5' 9' 5' 6' 5' 5'; D; 2.500 PER LINEAR FOOT.

| VALUE OF C: 7 | 6 | 5 | 4 | 3 | 2 | L | 1: B | 2: A | 2: B | 3: A | 3: B | 4: A | 4: B | 5: A | 5: B | 6: A | 6: B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | W= | 12.500 | 25.000 | | 25.000 | | 25.000 | | 25.000 | | 16.250 | |
| | | | | | 1.00 | 10 | 5.0 | 2.5 | $\overline{12.5}$ | $\overline{12.5}$ ○ | $\overline{12.5}$ | $\overline{12.5}$ ○ | $\overline{12.5}$ | $\overline{12.5}$ | 1.6 | 2.5 | 8.1 |
| | | | 3.00 | .44 | .50 | 20 | 26.0 | 7.5 | $\overline{37.5}$ | 23.1 | 32.1 | 32.5 ○ | 24.4 | $\overline{37.5}$ | 13.8 | 22.5 | 22.8 |
| | | 3.46 | 2.00 | .86 | .33 | 30 | 48.3 | 9.2 | $\overline{53.8}$ | 27.9 | 46.7 | 42.5 | 33.2 | 52.9 | 28.2 | 45.0 | 33.9 |
| 5.73 | 5.12 | 2.59 | 1.50 | .72 | .25 | 40 | 65.7 | 10.0 | $\overline{69.3}$ | 30.3 | 61.8 | 47.5 | 51.8 | 61.9 | 39.6 | 61.3 | 47.5 |
| 5.29 | [illegible] | 2.07 | 1.20 | .57 | .20 | 50 | 82.0 | 10.5 | 83.9 | 31.8 | 74.2 | 50.5 | 63.9 | 66.8 | 53.7 | 71.5 | 65.8 |
| | | | | | | 60 | 96.7 | 10.8 | 97.0 | 32.7 | 88.5 | 52.5 | 79.9 | 70.2 | 71.4 | 78.3 | 82.8 |
| | | | | | | 70 | 110.7 | 11.1 | $\overline{113.7}$ | 33.4 | 105.8 | 53.9 | 97.1 | 72.7 | 87.7 | 83.2 | 99.1 |
| | | | | | | 80 | 127.5 | 11.3 | $\overline{130.3}$ | 33.9 | 122.0 | 55.0 | 113.3 | 74.6 | 108.8 | 86.9 | 114.8 |
| | | | | | | 90 | 144.5 | 11.4 | $\overline{146.5}$ | 34.3 | 138.1 | 55.8 | 129.2 | 76.0 | 119.3 | 89.7 | 129.4 |
| | | | | | | 100 | 160.8 | 11.5 | $\overline{162.5}$ | 34.6 | 153.6 | 56.5 | 144.0 | 77.1 | 133.8 | 92.0 | 143.6 |
| | | | | | | 110 | 176.7 | 11.6 | $\overline{177.5}$ | 34.9 | 168.3 | 57.0 | 158.4 | 78.1 | 148.0 | 93.9 | 157.4 |
| | | | | | | 120 | 191.8 | 11.7 | $\overline{192.7}$ | 35.1 | 182.6 | 57.5 | 172.5 | 78.9 | 161.9 | 95.4 | 171.1 |
| | | | | | | 130 | 206.4 | 11.7 | $\overline{206.4}$ | 35.3 | 196.6 | 57.9 | 186.4 | 79.5 | 175.6 | 96.7 | 184.6 |
| | | | | | | 140 | 220.8 | 11.8 | $\overline{220.4}$ | 35.4 | 210.4 | 58.2 | 200.0 | 80.1 | 189.2 | 97.9 | 197.9 |
| | | | | | | 150 | 234.9 | 11.8 | $\overline{234.2}$ | 35.6 | 224.1 | 58.5 | 213.5 | 80.6 | 202.6 | 98.8 | 211.1 |
| | | | | | | 160 | 248.8 | 11.9 | $\overline{247.8}$ | 35.7 | 237.5 | 58.8 | 226.9 | 81.0 | 215.8 | 99.7 | 224.3 |
| | | | | | | 170 | 262.6 | 11.9 | $\overline{261.3}$ | 35.8 | 250.9 | 59.0 | 240.2 | 81.4 | 229.0 | 100.4 | 237.3 |
| | | | | | | 180 | 276.2 | 11.9 | $\overline{274.7}$ | 35.9 | 264.2 | 59.2 | 253.3 | 81.7 | 242.1 | 101.1 | 250.3 |
| | | | | | | 190 | 289.7 | 12.0 | $\overline{288.0}$ | 36.0 | 277.4 | 59.3 | 266.5 | 82.0 | 255.2 | 101.7 | 263.3 |
| | | | | | | 200 | 303.1 | 12.0 | $\overline{301.3}$ | 36.1 | 290.5 | 59.5 | 279.5 | 82.3 | 268.2 | 102.3 | 276.2 |
| | | | | | | 210 | 316.4 | 12.0 | $\overline{314.4}$ | 36.1 | 303.6 | 59.5 | 292.5 | 82.6 | 281.1 | 102.7 | 289.0 |
| | | | | | | 220 | 329.6 | 12.0 | $\overline{327.5}$ | 36.2 | 316.6 | 59.8 | 305.5 | 82.8 | 294.0 | 103.2 | 301.8 |
| | | | | | | 230 | 342.8 | 12.1 | $\overline{340.5}$ | 36.3 | 329.6 | 59.9 | 318.4 | 83.0 | 306.9 | 103.6 | 314.6 |
| | | | | | | 240 | 355.9 | 12.1 | $\overline{353.5}$ | 36.3 | 342.5 | 60.0 | 331.3 | 83.2 | 319.7 | 104.0 | 327.4 |
| | | | | | | 250 | 368.9 | 12.1 | $\overline{366.5}$ | 36.4 | 355.4 | 60.1 | 344.1 | 83.4 | 332.5 | 104.3 | 340.2 |
| | | | | | | 260 | 382.0 | 12.1 | $\overline{379.4}$ | 36.4 | 366.3 | 60.2 | 356.9 | 83.5 | 345.3 | 104.6 | 352.9 |
| | | | | | | 270 | 394.9 | 12.1 | $\overline{392.3}$ | 36.4 | 381.1 | 60.3 | 369.7 | 83.7 | 358.1 | 104.9 | 365.6 |
| | | | | | | 280 | 407.9 | 12.1 | $\overline{405.2}$ | 36.5 | 394.0 | 60.4 | 382.5 | 83.8 | 370.8 | 105.2 | 378.3 |
| | | | | | | 290 | 420.8 | 12.2 | $\overline{418.0}$ | 36.5 | 406.8 | 60.4 | 395.3 | 83.9 | 383.5 | 105.4 | 391.0 |
| | | | | | | 300 | 433.7 | 12.2 | $\overline{430.8}$ | 36.5 | 419.5 | 60.5 | 408.0 | 84.0 | 396.3 | 105.7 | 403.7 |

| L | 7: A | 7: B | 8: A | 8: B | 9: A | 9: B | 10: A | 10: B | 11: A | 11: B | 12: A | 12: B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W= | 16.250 | | 16.250 | | 16.250 | | 12.500 | | 25.000 | | 25.000 | |
| 10 | 8.1 | 6.5 | 6.5 | 8.1 | 8.1 | 2.5 | 3.3 | 5.0 | 2.5 | $\overline{12.5}$ | $\overline{12.5}$ ○ | 12.5 |
| 20 | 20.9 | 19.3 | 18.7 | 16.6 | 22.8 | 12.5 | 16.3 | 26.3 | 10.8 | $\overline{37.5}$ | 23.1 | 32.1 |
| 30 | 41.9 | 30.4 | 36.8 | 31.5 | 35.6 | 31.7 | 30.3 | 48.3 | 23.3 | $\overline{53.8}$ | 35.0 | 46.7 |
| 40 | 61.4 | 47.2 | 56.8 | 51.4 | 54.5 | 51.3 | 44.6 | 65.7 | 36.0 | $\overline{69.3}$ | 48.2 ○ | 61.8 |
| 50 | 74.9 | 65.7 | 73.7 | 68.5 | 73.9 | 68.4 | 63.2 | 82.0 | 50.8 | $\overline{84.0}$ | 61.1 ○ | 74.9 |
| 60 | 83.9 | 82.5 | 85.6 | 85.0 | 88.4 | 84.7 | 81.0 | 96.9 | 69.0 ○ | $\overline{97.5}$ | 77.5 | 87.8 |
| 70 | 90.3 | 98.6 | 94.1 | 100.6 | 98.8 | 99.4 | 94.8 | 110.9 | 85.6 ○ | 110.7 | 95.2 | 100.6 |
| 80 | 95.1 | 113.5 | 100.5 | 115.1 | 106.6 | 113.5 | 105.1 | 124.5 | 98.6 | 123.8 | 110.2 ○ | 113.4 |
| 90 | 98.8 | 127.8 | 105.4 | 129.1 | 112.7 | 127.3 | 113.2 | 137.9 | 108.0 | 136.7 | 121.8 | 126.1 |
| 100 | 101.8 | 141.8 | 109.4 | 142.8 | 117.6 | 140.8 | 119.6 | 151.1 | 116.9 | 149.5 | 131.2 | 138.7 |
| 110 | 104.3 | 155.5 | 112.6 | 156.3 | 121.6 | 154.1 | 124.9 | 164.2 | 123.5 | 162.3 | 138.8 | 151.3 |
| 120 | 106.3 | 169.0 | 115.3 | 169.6 | 124.8 | 167.3 | 129.3 | 177.2 | 129.1 | 175.0 | 145.1 | 163.9 |
| 130 | 108.0 | 182.4 | 117.6 | 182.8 | 127.6 | 180.4 | 133.0 | 190.1 | 133.8 | 187.7 | 150.5 | 176.5 |
| 140 | 109.5 | 195.6 | 119.5 | 195.9 | 130.0 | 193.4 | 136.1 | 202.9 | 137.8 | 200.4 | 155.1 | 189.1 |
| 150 | 110.8 | 208.7 | 121.2 | 209.0 | 132.1 | 206.4 | 138.9 | 215.7 | 141.3 | 213.0 | 159.1 | 201.6 |
| 160 | 111.9 | 221.8 | 122.7 | 221.9 | 133.9 | 219.3 | 141.3 | 228.5 | 144.3 | 225.6 | 162.6 | 214.2 |
| 170 | 112.9 | 234.7 | 124.0 | 234.8 | 135.5 | 232.1 | 143.4 | 241.2 | 147.0 | 238.2 | 165.7 | 226.7 |
| 180 | 113.8 | 247.7 | 125.2 | 247.7 | 137.0 | 244.9 | 145.3 | 254.0 | 149.4 | 250.8 | 168.4 | 239.3 |
| 190 | 114.6 | 260.6 | 126.2 | 260.5 | 138.3 | 257.7 | 147.0 | 266.6 | 151.5 | 263.4 | 170.9 | 251.8 |
| 200 | 115.3 | 273.4 | 127.2 | 273.3 | 139.4 | 270.4 | 148.6 | 279.3 | 153.5 | 276.0 | 173.1 | 264.4 |
| 210 | 115.9 | 286.2 | 128.0 | 286.0 | 140.4 | 283.1 | 149.9 | 292.0 | 155.2 | 288.6 | 175.1 | 276.9 |
| 220 | 116.5 | 299.0 | 128.8 | 298.8 | 141.4 | 295.8 | 151.2 | 304.6 | 156.8 | 301.1 | 176.9 | 289.4 |
| 230 | 117.0 | 311.8 | 129.5 | 311.5 | 142.3 | 308.5 | 152.3 | 317.2 | 158.2 | 313.7 | 178.5 | 301.9 |
| 240 | 117.5 | 324.5 | 130.2 | 324.2 | 143.0 | 321.2 | 153.4 | 329.8 | 159.5 | 326.3 | 180.1 | 314.5 |
| 250 | 118.0 | 337.2 | 130.7 | 336.9 | 143.8 | 333.8 | 154.3 | 342.4 | 160.8 | 338.8 | 181.5 | 327.0 |
| 260 | 118.4 | 349.9 | 131.3 | 349.5 | 144.4 | 346.5 | 155.2 | 355.0 | 161.9 | 351.4 | 182.8 | 339.5 |
| 270 | 118.8 | 362.6 | 131.8 | 362.2 | 145.1 | 359.1 | 156.1 | 367.6 | 162.9 | 363.9 | 183.9 | 352.0 |
| 280 | 119.1 | 375.3 | 132.3 | 374.8 | 145.6 | 371.7 | 156.8 | 380.2 | 163.9 | 376.4 | 185.1 | 364.5 |
| 290 | 119.5 | 388.0 | 132.7 | 387.5 | 146.2 | 384.3 | 157.5 | 392.8 | 164.8 | 389.0 | 186.8 | 377.1 |
| 300 | 119.8 | 400.6 | 133.1 | 400.1 | 146.7 | 396.9 | 158.2 | 405.4 | 165.6 | 401.5 | 187.1 | 389.6 |

| L | 13: A | 13: B | 14: A | 14: B | 15: A | 15: B | 16: A | 16: B | 17: A | 17: B | 18: A | 18: B | D | A (W=0.0) | B (W=0.0) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W= | 25.000 | | 25.000 | | 16.250 | | 16.250 | | 16.250 | | 16.250 | | | | |
| 10 | $\overline{12.5}$ ○ | $\overline{12.5}$ | $\overline{12.5}$ | 1.6 | 2.5 | 8.1 | 8.1 | 6.5 | 6.5 | 8.1 | 8.1 | 3.1 | | | |
| 20 | 32.5 ○ | 24.4 | $\overline{37.5}$ | 13.8 | 22.5 | 22.8 | 20.9 | 19.7 | 18.7 | 18.4 | 22.8 | 14.1 | | | |
| 30 | 44.7 ○ | 38.2 | 52.9 | 28.2 | 45.0 | 34.8 | 41.9 | 31.5 | 35.8 | 30.2 | 35.6 | 26.0 | | | |
| 40 | 58.1 ○ | 51.9 | 66.8 | 40.5 | 61.3 | 47.0 | 61.4 | 43.6 | 56.8 | 42.3 | 54.5 | 38.3 | | | |
| 50 | 71.3 | 64.5 | 81.1 | 52.9 | 76.4 | 59.4 | 76.5 | 55.9 | 73.7 | 54.6 | 73.9 | 50.5 | | | |
| 60 | 86.1 | 77.1 | 94.6 | 65.3 | 91.3 | 71.8 | 91.7 | 68.2 | 89.1 | 67.0 | 89.5 | 63.0 | | | |
| 70 | 103.8 | 89.7 | 111.1 | 77.8 | 105.4 | 84.2 | 106.1 | 80.6 | 104.3 | 79.4 | 104.9 | 75.4 | | | |
| 80 | 120.2 | 102.2 | 128.6 | 90.3 | 122.3 | 96.6 | 121.7 | 93.0 | 118.8 | 91.8 | 119.6 | 87.9 | | | |
| 90 | 133.5 ○ | 114.7 | 143.8 | 102.7 | 139.8 | 109.1 | 138.4 | 105.5 | 135.3 | 104.2 | 135.1 | 100.3 | | | |
| 100 | 144.2 ○ | 127.3 | 155.9 | 115.2 | 154.8 | 121.6 | 155.7 | 117.9 | 152.6 | 116.7 | 152.5 | 112.8 | | | |
| 110 | 152.9 | 139.8 | 165.8 ○ | 127.7 | 167.1 | 134.0 | 169.4 | 130.4 | 168.1 | 129.1 | 168.9 | 125.3 | | | |
| 120 | 160.1 | 152.3 | 174.1 | 140.2 | 177.3 ○ | 146.5 | 180.8 | 142.9 | 180.9 | 141.6 | 183.1 | 137.8 | | | |
| 130 | 166.3 | 164.8 | 181.1 | 152.7 | 186.0 | 159.0 | 190.5 | 155.3 | 191.8 ○ | 154.1 | 195.1 | 150.2 | | | |
| 140 | 171.5 | 177.3 | 187.1 | 165.1 | 193.4 | 171.5 | 198.7 | 167.8 | 201.2 | 166.6 | 205.3 ○ | 162.7 | D | A | B |
| 150 | 176.1 | 189.8 | 192.3 | 177.6 | 199.9 | 184.0 | 205.9 | 180.3 | 209.3 | 179.0 | 214.2 | 175.2 | 8 | 219.3 ○ | 187.5 |
| 160 | 180.1 | 202.4 | 196.8 | 190.1 | 205.5 | 196.4 | 212.2 | 192.8 | 216.3 | 191.5 | 222.0 | 187.7 | 18 | 229.7 ○ | 200.0 |
| 170 | 183.6 | 214.9 | 200.8 | 202.6 | 210.5 | 208.9 | 217.7 | 205.3 | 222.6 | 204.0 | 223.9 | 200.2 | 28 | 240.4 ○ | 212.5 |
| 180 | 186.8 | 227.4 | 204.4 | 215.1 | 214.9 | 221.4 | 222.6 | 217.7 | 228.1 | 216.5 | 235.0 | 212.7 | 38 | 251.4 ○ | 225.0 |
| 190 | 189.6 | 239.9 | 207.6 | 227.6 | 218.8 | 233.9 | 227.0 | 230.2 | 233.1 | 229.0 | 240.6 | 225.2 | 48 | 262.5 ○ | 237.5 |
| 200 | 192.1 | 252.4 | 210.5 | 240.1 | 222.4 | 246.4 | 231.0 | 242.7 | 237.6 | 241.5 | 245.4 | 237.7 | 58 | 273.6 ○ | 250.0 |
| 210 | 194.4 | 264.9 | 213.0 | 252.6 | 225.6 | 258.9 | 234.6 | 255.2 | 241.6 | 254.0 | 249.8 | 250.1 | 68 | 285.1 ○ | 262.5 |
| 220 | 196.4 | 277.4 | 215.4 | 265.1 | 228.5 | 271.4 | 237.8 | 267.7 | 245.3 | 266.4 | 253.8 | 262.6 | 78 | 296.6 ○ | 275.0 |
| 230 | 198.3 | 289.9 | 217.6 | 277.6 | 231.2 | 283.9 | 240.8 | 280.2 | 248.6 | 278.9 | 257.5 | 275.1 | 88 | 308.2 ○ | 287.5 |
| 240 | 200.1 | 302.4 | 219.5 | 290.1 | 233.7 | 296.4 | 243.5 | 292.7 | 251.7 | 291.4 | 260.9 | 287.6 | 98 | 319.8 ○ | 300.0 |
| 250 | 201.7 | 314.9 | 221.4 | 302.6 | 235.9 | 308.9 | 246.0 | 305.2 | 254.6 | 303.9 | 264.0 | 300.1 | 108 | 331.5 ○ | 312.5 |
| 260 | 203.1 | 327.4 | 223.0 | 315.1 | 238.0 | 321.4 | 248.4 | 317.7 | 257.2 | 316.4 | 266.9 | 312.6 | 116 | 343.3 ○ | 325.0 |
| 270 | 204.5 | 339.9 | 224.6 | 327.6 | 239.9 | 333.9 | 250.5 | 330.2 | 259.6 | 328.8 | 269.8 | 325.1 | 128 | 355.1 ○ | 337.5 |
| 280 | 205.8 | 352.4 | 226.0 | 340.1 | 241.7 | 346.4 | 252.5 | 342.7 | 261.8 | [illegible] | 272.0 | 337.6 | 138 | 367.0 ○ | 350.0 |
| 290 | 206.9 | 364.9 | 227.4 | 352.6 | 243.4 | 358.9 | 254.3 | 355.2 | 263.9 | 353.9 | 274.3 | 350.1 | 148 | 378.9 ○ | 362.5 |
| 300 | 208.1 | 377.4 | 228.6 | 365.1 | 244.9 | 371.4 | 256.0 | 367.6 | 265.9 | 366.4 | 276.5 | 362.6 | 158 | 390.8 ○ | 375.0 |

## EXPLANATION OF TABLE.

A is the right hand end shear of a span which is of L length when the wheel shown at top of column A is over right hand end of span

B is the left hand end shear of a span which is of L length when the wheel shown at top of column B is over left hand end of span

C is the left hand stringer reaction which is of L length when the wheel shown at top of column is over right hand end of stringer. This is not a maximum stringer reaction.

W is the wheel load.

L is the span length for which the shears were calculated. It may be called L'. It need not be the length of span under consideration.

D is the distance from beginning of uniform load to point where A+B+W is maximum

The Maximum

All shears are over-lined which give A+W or B+W, maximum. Thus $\overline{220.4}$

All shears have a circle between them which give A+B+W maximum when L and L' are equal Thus 177.3 ○ 146.5. This maximum occurs within the uniform load when L equals 146 or over.

The wheel is listed in an auxiliary table which gives A (for L) + B (for L') + W maximum when L and L' are unequal. This table combines certain spans up to 140 with others up to 300. The shorter span is ahead followed by the longer one except where the wheel is overlined. Spans not listed in table can have this maximum found by inspection or by trial. The point which gives this maximum is the distance D, given opposite the shorter span, from the beginning of the uniform load, when a span over 140 is combined with a span of greater length.

ten
left
pla
rig
*cre*

me
figi
of
tur

poi
the
is t
]
tic
du
cer
abi
act
gre

spa

spa
wh

po
she
of
qu
cei

in

wi
eit
the

ma
tei

en

ma
m

position of the load at which these maxima are found, and are, therefore, useful only for determining these shears, while this table can be used in calculating the maximum stress in every member of any bridge of ordinary type.

*Distance Between Wheels.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U.L | 109 | 101 | 96 | 91 | 86 | 77 | 72 | 66 | 61 | 53 | 45 | 40 | 35 | 30 | 21 | 16 | 10 | 5 |
| 18 | 104 | 96 | 91 | 86 | 81 | 72 | 67 | 61 | 56 | 48 | 40 | 35 | 30 | 25 | 16 | 11 | 5 | |
| 17 | 99 | 91 | 86 | 81 | 76 | 67 | 62 | 56 | 51 | 43 | 35 | 30 | 25 | 20 | 11 | 6 | | |
| 16 | 93 | 85 | 80 | 75 | 70 | 61 | 56 | 50 | 45 | 37 | 29 | 24 | 19 | 14 | 5 | | | |
| 15 | 88 | 80 | 75 | 70 | 65 | 56 | 51 | 45 | 40 | 32 | 24 | 19 | 14 | 9 | | | | |
| 14 | 79 | 71 | 66 | 61 | 56 | 47 | 42 | 36 | 31 | 23 | 15 | 10 | 5 | | | | | |
| 13 | 74 | 66 | 61 | 56 | 51 | 42 | 37 | 31 | 26 | 18 | 10 | 5 | | | | | | |
| 12 | 69 | 61 | 56 | 51 | 46 | 37 | 32 | 26 | 21 | 13 | 5 | | | | | | | |
| 11 | 64 | 56 | 51 | 46 | 41 | 32 | 27 | 21 | 16 | 8 | | | | | | | | |
| 10 | 56 | 48 | 43 | 38 | 33 | 24 | 19 | 13 | 8 | | | | | | | | | |
| 9 | 48 | 40 | 35 | 30 | 25 | 16 | 11 | 5 | | | | | | | | | | |
| 8 | 43 | 35 | 30 | 25 | 20 | 11 | 6 | | | | | | | | | | | |
| 7 | 37 | 29 | 24 | 19 | 14 | 5 | | | | | | | | | | | | |
| 6 | 32 | 24 | 19 | 14 | 9 | | | | | | | | | | | | | |
| 5 | 23 | 15 | 10 | 5 | | | | | | | | | | | | | | |
| 4 | 18 | 10 | 5 | | | | | | | | | | | | | | | |
| 3 | 13 | 5 | | | | | | | | | | | | | | | | |
| 2 | 8 | | | | | | | | | | | | | | | | | |

*Wheel which gives maximum Concentration*

| Span Lengths | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300-290 280-270-260 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 17 | 18 |
| 250-240-230 220-210-200 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 17 | 18 |
| 190-180 170-160-150 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 9 | 11 | 12 | 12 | 13 | 14 | 15 | 17 | 18 |
| 140 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 15 | 17 | 18 |
| 130 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 15 | 17 | |
| 120 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 13 | 14 | 15 | | |
| 110 | 3 | 3 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 13 | 14 | | | |
| 100 | 3 | 3 | 3 | 4 | 5 | 5 | 6 | $\overline{14}$ | $\overline{14}$ | $\overline{14}$ | $\overline{13}$ | $\overline{13}$ | 11 | 12 | 13 | 13 | | | | |
| 90 | 3 | 3 | 4 | 4 | 5 | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | 12 | 13 | | | | | |
| 80 | 3 | 3 | 4 | 4 | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | 12 | | | | | | |
| 70 | 3 | 3 | 4 | 4 | $\overline{13}$ | $\overline{13}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{11}$ | $\overline{11}$ | 11 | | | | | | | |
| 65 | 3 | 3 | 4 | 4 | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{12}$ | $\overline{11}$ | $\overline{11}$ | 11 | | | | | | | | |
| 60 | 3 | 3 | 3 | 4 | 5 | $\overline{13}$ | $\overline{12}$ | $\overline{11}$ | $\overline{11}$ | $\overline{11}$ | 11 | | | | | | | | | |
| 55 | 12 | 12 | 12 | 4 | 12 | $\overline{13}$ | $\overline{12}$ | $\overline{12}$ | $\overline{13}$ | 11 | | | | | | | | | | |
| 50 | 12 | 12 | 12 | 12 | 12 | $\overline{13}$ | $\overline{13}$ | $\overline{13}$ | 12 | | | | | | | | | | | |
| 45 | 3 | 12 | 12 | 12 | 12 | $\overline{13}$ | $\overline{13}$ | 13 | | | | | | | | | | | | |
| 40 | 3 | 3 | 3 | 12 | 12 | $\overline{13}$ | 13 | | | | | | | | | | | | | |
| 35 | 3 | 3 | 4 | 4 | 13 | 13 | | | | | | | | | | | | | | |
| 30 | 3 | 3 | 4 | 4 | 13 | | | | | | | | | | | | | | | |
| 25 | 3 | 3 | 4 | 4 | | | | | | | | | | | | | | | | |
| 20 | $\overline{4}$ | 3 | 4 | | | | | | | | | | | | | | | | | |
| 15 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 10 | 3 | | | | | | | | | | | | | | | | | | | |

*The shorter span is ahead followed by the longer one except where the wheel is overlined*

THE FORMULAE.

To find a Abutment Reaction for a Single Span

The abutment reaction per rail for a span of $L$ length, for any wheel is $A+W$ if span is to left, or $B+W$ if span is to the right of that wheel.

To find a center Pier Reaction for two Equal Spans

The center pier reaction per rail for two equal spans of $L$ length for any wheel is $A+B+W$.

To find a center Pier reaction for two Unequal Spans

The center pier reaction per rail for two unequal spans of lengths $L$ and $L'$ for any wheel is $A(\text{for } L)+B(\text{for } L')+W$.

To find Moment at the Center of a Span.

The moment at the center of any span which is not divided into panels or has a floorbeam at center and the length of which is $2L$, is $[A+B+W]L \div 2$.

To find Moment at any point in any Span

The moment at any point which is $L$ distance from one end of any span which has no panels, or has a floorbeam at this point, and which is of $L$ and $L'$ length is $[A(\text{for } L)+B(\text{for } L')+W]LL' \div [L+L']$

To find the End Shear of any Span.

First— The end shear of any span which has no panels, is the same as the abutment reaction for that span. Second— The end shear is the shear in the first panel, if the span has panels.

To find Shear at any point of any Span.

First— The shear in any span, which has no panels, at a distance $L$ from right abutment is $\dfrac{[B(\text{for } L)+W]L-W(\text{for } 1)z-W(\text{for } 2)y}{\text{Span}}$ when the wheels in front of the point are distant from the left abutment, $z$ for wheel 1, and $y$ for wheel 2.

Second— The shear in front of any panel point which is $L$ distance from right abutment and $z+L'$ from left abutment, the panel in front of the point being $L'$ long, is $\dfrac{[B(\text{for } L)+A(\text{for } L')+W]L-C(\text{for } L')z}{\text{Span}}$.

A graphical example is given by Example I, illustrating the determination of maximum abutment-reaction for a 180 ft. span. Running down the column headed L until we come to 180, and then following horizontally along this 180 ft. line until we come to an overlined shear, we discover it to occur under wheel 2 in column B, the amount being 274.7 thousands of pounds, to which must be added the weight of wheel 2, or 25,000 pounds, making the total 299.7 thousands of pounds. This reaction occurs when wheel 2 is over the left hand abutment of the span.

The pier-reactions are found by adding together shears A and B, together with the weight of the wheel immediately over the shears

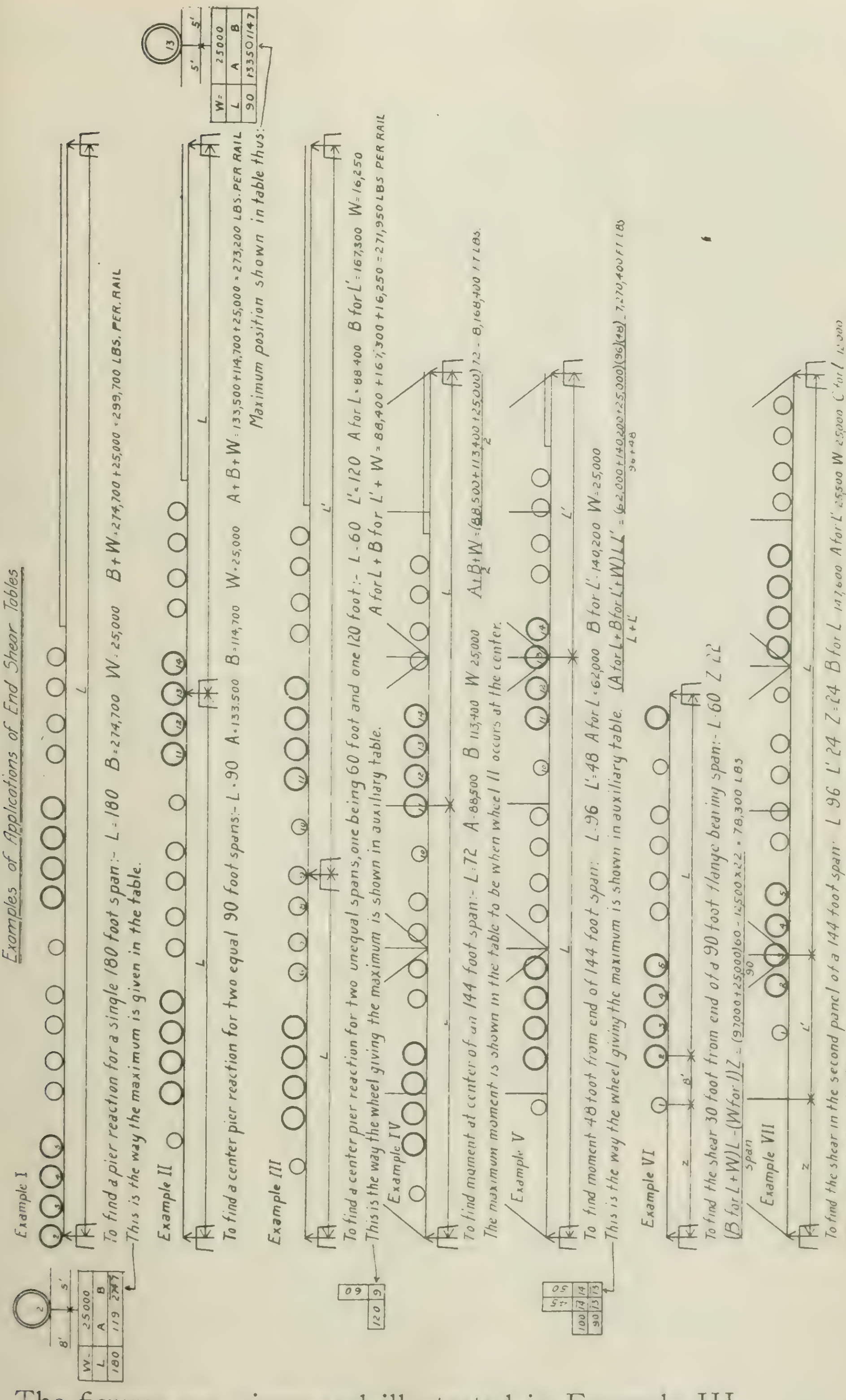
used. For equal spans the *maximum* pier-reaction occurs where the shears A and B are separated by a small circle. A indicates the shear coming on to the pier from the left hand, and B indicates the shear coming on to the pier from the right hand side. We therefore get the pier reaction by adding to the sum of these two shears the wheel load at the top of the column. Example II illustrates this for two 90 ft. spans.

The table is direct reading for maximum center-pier reaction in this manner for spans up to 150 ft. in length; but for spans of greater length the maximum pier reaction, as indicated by the circled shears, does not occur until a portion of the uniform load has crossed the pier. The little auxiliary table which commences at the 150 ft. line indicates just what portion of the uniform load must cross the pier in order to produce a maximum pier reaction for two equal spans of length indicated at the left hand margin. The figures in column A indicate, as before, the right hand shears. Inasmuch as the pier is now under the uniform load, there is no wheel load to consider, as is indicated by the O.O at top of the column for W. The reactions are, therefore, the same as the shears, and the pier-reaction is found by adding the two shears A and B for the span in question.

For example, consider the pier reaction caused by two equal spans each 160 feet long. We find the maximum when 18 ft. of the uniform load has passed the center of the pier, and the amount of the reaction of the pier is 229.7 plus 200.0 (with no wheel load to add), making a total of 429.7 thousands of pounds.

For spans of unequal length, the pier reactions under any wheel may be found by adding together Shear A for one span and Shear B under the same wheel for the other span, together with the weight of the wheel at the point. The maximum pier reaction for spans of unequal length is found under the wheel indicated in the auxiliary table provided for this purpose. This auxiliary table appears as being labeled "Wheel which gives maximum concentration." Span lengths are indicated in horizontal lines across top of table, and in vertical column down the side, and the number found at the intersection of the lines for any two spans gives the wheel which will cause maximum pier reaction when placed directly over pier common to the two spans considered. Thus, a pier supporting spans 60 and 120 ft. long will give a maximum reaction when wheel 9 is over the pier, and this number 9, not being over-lined in the auxiliary table, indicates that the shorter span is ahead, followed by the longer, this relative location being necessary on account of the fact that the locomotives are assumed to be always traveling from right to left. Knowing the position of the loads, we now simply have to read the table for the following, and sum the results.

Right hand shear "A" for the 60 ft. span at left of pier (wheel 9).
Left hand shear "B" for the 120 ft. span at right of pier (wheel 9).
Weight of wheel 9.




The figures are given and illustrated in Example III.

The maximum pier reaction is not only useful for determination of pier and tower loadings, but it is direct factor in the calculation of the maximum-moment based on an important proposition,

the truth of which is demonstrated by Mr. Gibson in an appendix to this paper. The proposition is as follows, being original with Mr. Gibson:

*"The moment at any point in a span is equal to the moment produced by the application at that point of an imaginary load equal to the pier reaction of two imaginary spans joining at the point in question, and of lengths equal to the right and left hand portions of the span, measured from the point. It follows that this moment is a maximum when the pier or panel concentration of the two imaginary spans is a maximum."*

To find the maximum moment at any point of any span we can, therefore, imagine the span to be cut in two at that point and supported by a pier thereunder. Ascertain the pier-reaction for such a combination of spans, then use this pier-reaction as a concentrated load on the original full length span applied at the point for which the moment is sought, and figure as a simple span for this concentrated load. The resulting moment for the imaginary load is the actual moment in the span.

This is figured out and illustrated in Example IV, for a 144 ft. span at the center, subdividing it into two imaginary 72 ft. spans; and in Example V for the same length of span at a point 48 ft. from the end, dividing the span for the purposes of calculation into a 48 ft. and a 96 ft. span. The rest of the calculation is merely a repetition of what has been previously explained, supplemented by the application of principles for finding the moment of a single concentrated load on a simple span.

A final use for the table is the finding of intermediate shears. While the formulæ for this are apparently longer and more involved, the operation is very simple and consists of merely dividing the span, as before, into two imaginary spans at the point for which shear is sought, and determining the imaginary concentrated load applied at this point. The reaction at the left is then found by multiplying this imaginary load by the distance to the right abutment and dividing by the span length. If there are any loads at the left of this point, their reaction on the right abutment of the entire span is subtracted from the above, the difference being the shear sought.

In case of a span with panels, this process is slightly simplified by an auxiliary table for values of C. These values of C being the left-hand end-shears for all panel lengths from 10 ft. to 50 ft. when the wheel indicated at the top of the little table is at the right hand of the panel or stringer. By this means, instead of subtracting the shears for each individual wheel, we can get a new imaginary load at the left hand end of the stringer, and treat it alone instead of treating separately all the loads which go to make it up, namely. —the loads on the panel in front of or to the left of the point on the span for which the shear is sought.

This method of finding shears at any point in any span is ex-

pressed by the formula given, analysis for which will disclose the above principles.

For ordinary work the stresses derived from these tables are probably more accurate than those found by any other method, for there is never any doubt as to the wheel producing the maximum stress on any member, whereas it frequently requires several trials to determine the absolute maximum from direct wheel-load calculations, and even then it is easy to overlook some condition that may give a slightly greater stress.

The accuracy of the table itself may be safely assumed, many of the calculations having been verified by Mr. Emil Kurtz, of this Society. The coincidence of results in the 210 ft. example is further proof of the arithmetical accuracy of the figures.

## ADDENDA BY MR. GIBSON.

The generally accepted criterion for a maximum moment states that the "average unit load on the left of the point, must be equal to the average unit load on the whole span." This would take into

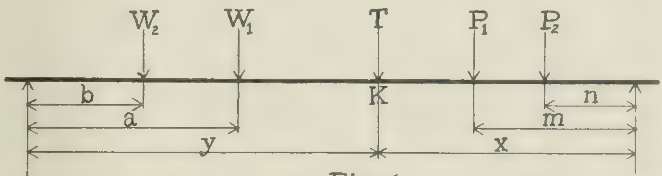



Fig. 1

Let $W_1, W_2, P_1, P_2$ and $T$ be the wheel loads which are $a, b, m$ and $n$ distance from the bearings. Then,

$$R_1 = \frac{P_1 m + P_2 n \cdots + Tx + W_1(x+y-a) + W_2(x+y-b) \cdots}{x+y}.$$

$$\text{Moment } M = \left[\frac{P_1 m + P_2 n \cdots + Tx + W_1(x+y-a) + W_2(x+y-b) \cdots}{x+y}\right] y - W_1(y-a) - W_2(y-b).$$

$$M(x+y) = P_1 my + P_2 ny \cdots + Txy + W_1 xy + W_1 y^2 - W_1 ay + W_2 xy + W_2 y^2 - W_2 by \cdots$$
$$- W_1 xy - W_1 y^2 + W_1 ax + W_1 ay - W_2 xy - W_2 y^2 + W_2 bx + W_2 by.$$

$$M(x+y) = P_1 my + P_2 ny \cdots + Txy + W_1 ax + W_2 bx.$$

$$M = \frac{\left(\frac{P_1 m + P_2 n \cdots}{x} + T + \frac{W_1 a + W_2 b \cdots}{y}\right) xy}{x+y}.$$

$$F = \frac{P_1 m + P_2 n \cdots}{x} + T + \frac{W_1 a + W_2 b \cdots}{y}.$$

$$M = \frac{Fxy}{x+y}. \qquad \frac{P_1 m + P_2 n \cdots}{x} \ (a). \qquad \frac{W_1 a + W_2 b \cdots}{y} \ (b).$$

account only the weight of the loads. It is evident that the position of the heavier wheels as well as their weight, has an influence on the maximum moment.

The following demonstration is given in order to arrive at a criterion, which not only considers the weight of the wheels but also

their respective positions. The criterion which is derived gives the condition under which the maximum always occurs.

In figure I is represented any deck span receiving any number of wheel loads. To find the moment at any point K, which is at a distance x and y from the right and left bearing respectively:

The last equation is that of a load at any point in a span, and is a maximum when F is a maximum for any given values of x and y. Therefore F is an equivalent load, which gives the same moment as the forces on the span.

The left hand reaction of a span of x length is given by the expression "a", and the right hand reaction of a span of y length is given by the expression "b". The wheel load at this point is T. Therefore F is the floor beam reaction between two panels of x and y length, and is a maximum when some wheel is at the point. The reaction for x and y is the same, whether or not it be subdivided into panels.

Therefore the criterion for the maximum moment at any point is:

*The moment at any point in a span is equal to the moment produced by the application at that point of an imaginary load equal to the pier reaction of two imaginary spans joining at the point in question, and of lengths equal to the right and left hand portions of the span, measured from the point. It follows that this moment is a maximum when the pier or panel concentration of the two imaginary spans is a maximum.*

## DISCUSSION.

Mr. W. L. Abbott (Chairman): This paper is evidently the product of great labor and study, and is what might be called strictly technical and quite beyond the appreciation of the layman.

Mr. Andrews Allen: I am one of those unfortunates who have been through a rigid and long continued apprenticeship in calculating stresses in all kinds of structure, and who has kept more or less in training ever since. Everyone who has to calculate railroad bridges has his own way of figuring. There are different methods almost *ad infinitum*, but the wheel load methods are usually employed, because they are adaptable to more conditions and express, nearer than any other methods, the exact conditions that occur in a railroad span, under the passage of a train. The methods of wheel load calculation can be classified as graphical or analytical.

The graphical methods are very clear, very accurate, and very elegant in their use, but they require a good deal of time and room, a draughting board, T square, and all the appliances of the office. Graphical methods cannot, therefore, be depended upon for general use, and engineers depending wholly upon them are at a decided disadvantage, especially when, as frequently happens, bridges have to be figured offhand, or away from the office. For this reason analytical methods, except for curved chord bridges, draw spans,

etc., are usually preferred by persons actively engaged in this work. The analytical methods are more elastic. One can figure an ordinary bridge analytically while riding on a train or wherever he happens to be, with the aid of a pocket slide rule.

The method presented by Mr. Curtis is also quite limited in its application. It will not apply to the more unusual forms of bridge; you cannot use it, at least in the form presented, for the web stresses in a curved chord bridge or for a draw span or continuous girder.

Neither will this method be of much service in the investigation of old bridges, which usually must be calculated for actual loads passing over the bridges under investigation, because of the immense amount of labor involved in calculating a complete table for each engine.

It is probably true, however, that 90 per cent of the bridges calculated by bridge companies, or bridge departments of our railroads, are simple spans of one sort or another, and are calculated for typical loading. For such calculations this method leads to a degree of accuracy that it is hard to obtain by other methods, without a great deal of experience in selecting the wheel which gives the maximum stress, or a great deal of effort consumed in trying different positions. The usual criterion will often be satisfied by several different wheels. Therefore, there are a number of different maxima, all of which satisfy the criterion, and it is necessary to try several positions unless one has had experience enough to judge at a glance which will give the absolute maximum.

This method is, therefore, an important addition to our methods of calculating bridges. It will not take the place of graphical methods nor analytical methods, but for one actually engaged in figuring stresses it is a useful and very accurate time-saver, and will be of invaluable service to bridge companies and to the bridge departments of our railroads.

I also wish to call special attention to the auxiliary table showing the wheel that gives the maximum concentration. This table is of general use. You can use it for tables when the other tables would not apply, or in connection with other methods of calculation.

The mathematical demonstration of the truth of Mr. Gibson's method of deducing moments from his tables is complete and conclusive, but it may also be well to call attention to the fact that the correctness of this proposition can also be established by the process of reasoning substantially as follows:

Suppose the span in question to be divided at a point at which moment is sought and connected in top and bottom chords by pins with slotted pinholes; then suppose that an upward force equal to the pier reaction of the two sections of the original span be applied at this point, it is evident that there will be no stress on the pins connecting the chords of the span at this point, and if an equal downward force is applied, it is evident, first, that this force will neutralize the vertical force previously applied, and, second, that

the moment at this point of the span will equal the moment from the original loads, before these imaginary loads were applied.

On the whole, I wish to congratulate Messrs. Curtis and Gibson for having presented to the profession something which is new—a table which has been worked out in a most painstaking manner and greatest accuracy, and of inestimable value to those actually engaged in the calculation of bridges; at the same time, a most useful table for the layman and for the man who calculates a bridge only occasionally. He can turn to it, as Mr. Curtis has stated, with scarcely any re-study, and the explanation given on the table itself is enough to enable a man to figure an ordinary span with the greatest accuracy.

Mr. E. N. Layfield: I think that this subject is almost beyond most of us to discuss offhand. A thing like that necessarily requires study to enable us to discuss it. There are several points in the paper—about the principles explained—that seem very small indeed now that they have been explained to us, and it might seem a wonder that some one did not think of them before, but from the fact that they did not, credit is due to the authors just as much as if it did not appear so simple, now that the matter has been put before us.

Mr. M. B. Wells: I have looked this paper over, to some extent, and think that Mr. Gibson and Mr. Curtis are deserving of a great deal of credit for the very ingenious demonstration, and for the painstaking work done upon the tables. I believe, however, that some of the statements made with regard to the ease with which these tables can be used by laymen are somewhat open to question. I do not believe a table of this kind should be used by anyone who is not thoroughly familiar with the ordinary methods of calculating shears and moments, and who has not looked into all of the reasons why this method is correct. The attempt of a man to use a table of this kind in a bridge problem, without being thoroughly familiar with the accepted criterions, would be very apt to lead to errors.

Mr. W. T. Curtis: The reference that has been made to the layman using this table may perhaps be misconstrued. My personal opinion of the table is that it can be used with safety by persons of ordinary capacity in the employ of bridge and railroad companies who have occasion to figure bridges, but who are not necessarily experts at figuring in this work; by men who understand enough of the elements of stress figuring to know what a moment is and how to take care of it. I would not turn the tables over to persons entirely at sea as to the manner of calculation, or to people who have to pick out beam loads from the Carnegie handbook. I concur in Mr. Wells' opinion that the table would not be safe in the hands of people whose experience is limited to that extent. I have not used the table myself as yet, to any great extent, but I really believe that a draughtsman of average intelligence can use this table readily, with very slight instruction, and with perfect

safety; in fact, with just as much safety as a non-technical contractor can pick up a Carnegie handbook and tell you how much a 15-inch I-beam 20 ft. long will stand.

MR. J. E. FERGUSON (by letter): The paper entitled "A New Method of Calculating Bridge Stresses by Means of End Shears," given before this society this evening, presents several features quite worthy of consideration in general practice and especially in such offices where it is found necessary to use but a comparatively small number of assumed engine loadings.

The table for any specified engine loading, worked out along the lines indicated in the paper, will be found to be quite lengthy, but when once computed and checked it may be absolutely correct, and is always thereafter ready for instant application.

Leaving the preparation out of consideration, by its use the stresses in a bridge of the ordinary type may be found more rapidly and with considerably less labor than is the case where any engine diagrams or tables, noticed by the writer, are employed. With most diagrams it is often necessary, even for a proficient engineer, to make several trials in order to get the proper wheel to give a maximum moment or shear. This takes time but the operations are so simple with the table presented that results may be quickly obtained. It is certainly quite an advantage to be able to almost instantly see the result before you. The simplicity of the operations also greatly reduces the liability of error. Anything tending toward simplicity is commendable.

Although the preparation of a table of this nature at first sight appears to be quite a formidable undertaking, a methodical treatment of the case with the use of the slide-rule will enable a person to run out the work in a comparatively short time. The writer would be pleased to know the approximate amount of time found necessary to compile a table of this description.

MR. J. GIBSON: I should say, roughly speaking, that some 300 to 400 hours work has been put on this table by myself, and I presume Mr. Kurtz has put in nearly that much time in the checking he did for me.

# THE CLAY SLIDE AT THE BOONE VIADUCT, BOONE, IOWA

A. W. Merrick, M. W. S. E.

*Presented April* 4, 1906.

The location of this slide is about four miles west of Boone, on the C. & N. W. Ry., main line, in Boone County, Iowa. This section of the main line is a cut off across the Des Moines River valley between Boone and Ogden. It is a double track line known as the Boone County Railway and was built in 1899-1901 to eliminate curves and grades on old single track line via Moingona. On the old line the maximum grade is 1.5 per cent. and maximum curvature 6°. The maximum grades and curves on the new line are respectively 0.5 per cent. and 2°. The total reductions effected by this new line are,—Distance 3 miles, ascent—East bound, 158 ft., ascent West bound 158 ft., curvature 834°, and maximum grade from 1.5 per cent. to 0.5 per cent.

The bridge across the Des Moines River on the new line is a double track steel viaduct consisting of a channel span of 300 ft., and approaches of alternate 75 ft., and 40 ft., deck plate girders supported on towers. The East approach is made up of eight 75-ft. spans and six 45-ft. spans, the first two spans being each 75-ft. long, supported by a rocker bent instead of a tower. The West approach consists of thirteen 75-ft. spans and twelve 45-ft. spans all resting on towers. The channel span is supported by "A" shaped steel bents resting on steel cylinders filled with concrete and capped with Ableman's sand-stone.

Each tower leg in the approaches rests on a stone pier. The foundation of all piers in East approach except Nos. 2, 3, 4, 5, 11 and 12, was carried down to a stratum of black shale. Piers Nos. 2, 3, 4, 5, are founded on hard clay, and piers Nos. 11 and 12 have pile foundations. The cylinder piers supporting the channel spans are carried down to a thick bed of sand-stone about 40-ft. below low water.

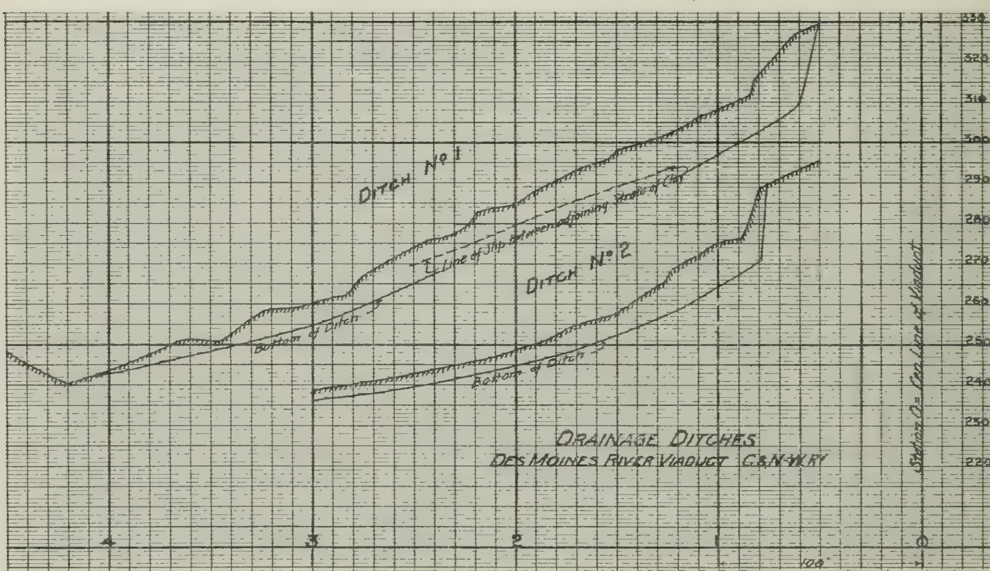
The surface formation of Boone County, is of glacial origin and belongs to the period called the Wisconsin drift. The Des Moines River valley is supposed to be a later formation. The river has cut through the drift and deep into the coal measures throughout its course in the county, leaving a valley bordered by precipitous bluffs deeply laid with glacial debris. The depth of the valley is approximately 180 to 200 feet. The glacial drift is between 60 and 80 feet deep at the upper edge of the valley and the debris on the sides of the slopes, is approximately 10 to 30 feet deep. Underlying the drift are alternate strata of clay, shale, coal, fire clay and sand stone. These strata lie in level planes and are rather thin, ranging from 2 ft. to about 20 ft. in thickness, and somewhat indiscriminately mixed, the coal being the thinnest and the fire clay and

sand stone the thickest layers. The accompanying profile shows the strata and the line of erosion as determined by borings along the line of the bridge.

The slip, or slide, occurred in the mixed clay of the glacial drift in the vicinity of piers Nos. 4 to 6 on the east bank of the river valley and on the North side of the viaduct. This is at an elevation of from 65 to 105 ft. above low water in the river. The first indication of any tendency of this surface material to slide was observed in the latter part of June, 1905, following a severe and unusually heavy rainfall during the last week of that month. An inspection of the situation showed a ditch-like depression about 12 ft. wide and 3 to 4 ft. deep running in a northeasterly direction and starting at a point about 50 ft. from pier No. 5. From the southwest end of the depression a crack extended towards the bridge coming up to pier No. 6 and running partly around that and then on, down the slope, towards pier No. 7. The bottom and sides of this depression were regular enough to, at first, suggest a belief that the settlement was caused by the caving in of an old heading in an abandoned coal mine north of the bridge. Subsequent developments proved this to be unlikely. It very soon became evident that the crack near pier No. 6 was deepening and lengthening as other cracks and fissures were appearing. The Chief Engineer was notified and he, in company with the Asst. Chief Engineer, made a trip to Boone and looked over the situation very carefully on June 30th. A plan for draining the side hill was immediately made at Mr. Carter's direction and work was commenced the following day. By this time further slips had taken place and the situation was about as shown on accompanying plan. In places where the vertical slip amounted to two feet or more the material rolled up below in a mud wave. It was impossible to walk in some parts of the side hill on account of the soft ground and these mud waves. The excessive amount of moisture in the ground caused the surfaces of two adjoining clay strata to slip upon each other making depressions, slips and waves in the overlaying earth.

The plan decided upon by Mr. Carter was to construct two large deep drains running down hill from the bridge at an angle of about 37° 30′ with the track. A sufficient number of branches were to be provided to thoroughly drain the area involved in the slide. The plan was carried out in every particular as proposed except an additional ditch No. 3 was built north of the first two. Before the excavation for the main ditches could proceed, it was found necessary to construct a temporary drainage ditch to dispose of the surface water. The main ditches are five feet wide on the bottom and vary in depth from about four feet at the lower end to nine or ten at upper end. Ditches Nos. 1 and 3 are each 360 ft. long with six branch ditches each. No. 2 is 230 ft. long and has five branches. The branches or laterals are the same size as the

main ditches. The bottoms of all ditches are filled to a depth of three feet with "one-man" rip-rap and on top of this is placed a layer of willow brush two ft. thick. The ditches are back-filled with material from the excavation. The ditches were opened up to whatever depth was necessary to get about one or two feet below the line of slip. A report of progress of the work dated July 30th stated that ditches Nos. 1 and 3 had been opened up for a distance of 250 ft. and 150 ft. respectively. It also says: "Since commencing work on these ditches the ground has slipped a distance of about



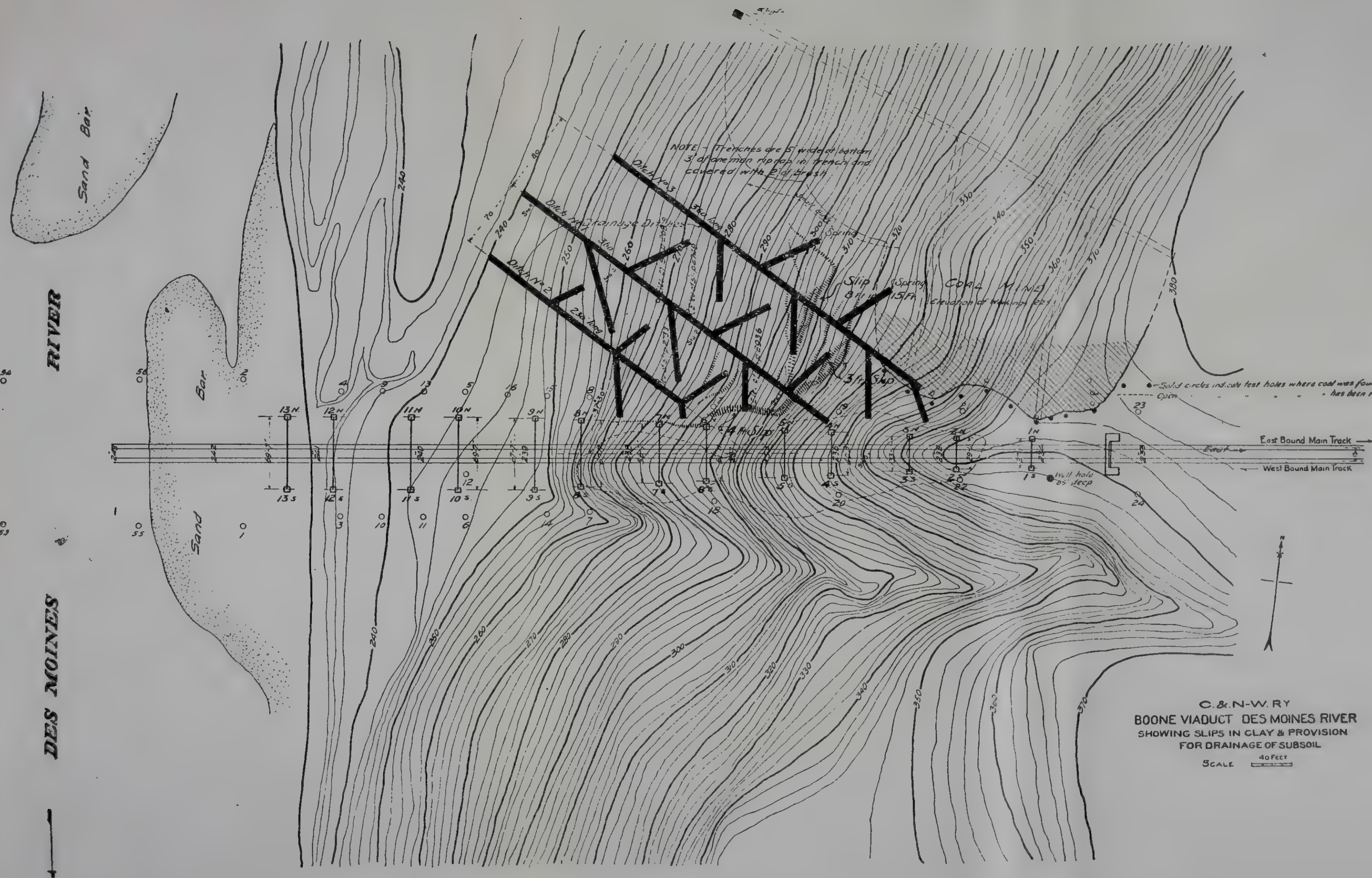

two feet all the way down the slope. The point where slipping takes place is about 8 feet below the surface." This line of slip was very well defined. It occurred along a very thin stratum of dark red clay about one-sixteenth inch thick between two layers of blue clay. As a matter of precaution a strut was placed between piers 5 and 6 on the north side. This was built up out of four (4) 8-in. by 16-in. fir timbers in pairs with diagonal braces between. No derangement or settlement of any piers occurred, however.

The work was completed September 1st, 1905. The working force varied from 20 to 70 men, great difficulty being experienced in getting and keeping a full force of men. As an illustration, 70 men were sent from Chicago during five days between July 19 and 26th. Seven of these men were working July 26th.

Thirty-nine cars of rip-rap were used besides a large amount of sheet piling and miscellaneous material. The cost was as follows:

| | |
|---|---|
| Material | $1,425.00 |
| Labor | 5,725.00 |
| Total | $7,150.00 |

The success of this drainage plan seems to be assured as the ground has dried out and slipping has been stopped.




C. & N-W. RY
BOONE VIADUCT DES MOINES RIVER
SHOWING SLIPS IN CLAY & PROVISION
FOR DRAINAGE OF SUBSOIL
SCALE 40 FEET


BOONE VIADUCT — DES MOINES RIVER

DISCUSSION

Mr. C. F. Loweth: The paper is a valuable contribution to the literature on earth slides, and the engineers in charge of the structure are to be congratulated on the prompt and effective measures taken to remedy the trouble.

Large masses of earth in natural position are sometimes so nicely balanced that their equilibrium is easily destroyed, and some of the causes which may destroy the balance and bring about earth slides are excavations in or under the surface, an excess of the usual amount of moisture, especially if it be absorbed by the earth, an extraneous loading, and the vibrations caused by heavy machinery or the passing of railway trains.

The extensive landslides on the line of the Canadian Pacific Railway in the Frazier River Valley in British Columbia were found to be due to the irrigation of large tracts of land above the line of the railroad.

The slide referred to in the paper developed soon after an unusually heavy rainfall, but in the writer's opinion it is probable that the weight of the viaduct and its traffic and the excavations of the old mines were contributing causes.

The popular conception of a landslide is that of a violent phenomenon; some surely are such, and all are the results of mighty forces in motion. But the writer believes that there are many earth movements, truly classed as slides, but which occur so slowly and with so little disturbance of the surface that they are unnoticed or unrecorded, especially if there are no artificial structures near by to be affected, or to serve as reference points from which the movement may be observed.

It is generally known that the east bank of the Missouri River at the Bismarck bridge of the Northern Pacific Railway slipped, moving the massive east river pier somewhat more than three feet, and the smaller bank abutment a greater distance. This moving or sliding became apparent before the bridge was completed in 1883, and continued with practically no cessation, but with varying rate, for 10 or 12 years.

In the early years the movement was slow and at times almost imperceptible, except as measured through long intervals. Finally the city water works pumping station was built on the lower bank just below the bridge, and two large reservoirs were built at the top of the bluff near the top of the cut through which the railroad approached the bridge. The pipe connecting the pump house and reservoirs passed under the bridge on the lower bank and was then turned up the hill about parallel with the line of the railroad and not more than a hundred feet or so therefrom. These reservoirs were far from water tight, and the movement of the hillside pulled the pipe joints apart several times, the results being that the hillside was unusually saturated and the earth movement became alarmingly

accelerated and threatened to carry the pier from under the bearings of the spans it carried, one of which was 400 feet long.

The climax was accompanied with the appearance of many fissures in the surface of the hillside, none of them, however, were so large but what they would be obliterated by the winds and rains of a few weeks, and so far as the writer is aware these were the first surface evidences of any sliding of this hillside.

As a contrast to this long continued and barely perceptible earth movement are the hillsides farther up the stream from this bridge, and in fact in many places along the Upper Missouri River, where the rough and tumbled surfaces clearly indicate earth slides of great magnitude and violence.

It may not be generally known that at the Bismarck bridge the sliding mass was doweled to the underlying stable shale by two large concrete dowels, each about 25 feet square and located just above and below the bridge axis; in addition the hillside has been under-drained, and the writer understands these measures have proven successful.

E. E. R. Tratman: In regard to the movement of the pier of the Bismarck bridge, mentioned by Mr. Loweth, it is interesting to note that instead of building a new pier it was decided to force the old pier back to its original position, a distance of about 44 inches. As described in "Engineering News" of April 28, 1898, from informaton furnished by Mr. E. H. McHenry, then Chief Engineer of the Northern Pacific Ry., the plan adopted was to build a series of tunnels under the pier, filling them partly with concrete, upon which was built a timber framework carrying lines of rails with steel rollers, rails resting upon the rollers took a bearing against the base of the pier. With the series of tunnels completed there were forty lines of rails and 960 rollers. Jacks bearing against the new concrete base were used to pull the pier back into place upon its new foundation. Another case of serious sliding due to the leakage of water was the reservoir at Portland, Ore., the peculiar conditions at which were described in a paper presented to the American Society of Civil Engineers about a year ago.

Prof. U. S. Grant, Evanston, Ill. (by letter): The movement of unconsolidated materials downward along steep slopes is a phenomenon of considerable importance geologically, as it is a factor in the gradual transfer of material from land to the sea. When this movement is exceedingly slow, the term creep is commonly applied to it. When more rapid, the moving mass is spoken of as a slide or slip, and if of large size is called a landslide. The presence of much water in these unconsolidated materials on steep slopes, especially when clayey substances are present, tends to make the movement more possible and more rapid.

Mr. L. K. Sherman: I would like to ask Mr. Merrick if that seam of red clay, on which the line of slide occurred, sloped down with the bank or whether it was horizontal?

Mr. Merrick: The profile of the ditch shows on the dotted line; it seems to be, in that case, not exactly parallel to the sections as shown in the sectional plan. In general it was very well defined—that small seam of clay.

Mr. E. C. Carter: The Des Moines River flows through a deep gorge, about half a mile wide on top, and from 400 to 600 feet wide at the bottom, where the bridge and new line cross. The hard clays and sandstone and shale strata are overlaid with a lighter earth or drift which has washed down and slipped down to form the surface of the present bluffs. As surface water soaks through this drift, it gets on to the more impermeable strata, and flowing along it works down until it finds some means of coming out through the hillside as a spring, and after a long continued wet season, or series of wet seasons, a sufficient quantity of water has accumulated and has soaked into the overlying stratum of drift, when it finally becomes semi-fluid, and movement will take place, relieving the support of the overlying material, which then subsides by a crack, leaving a nearly vertical face of 3 or 4 feet. This action becomes successive step by step up the sides of the hill. In the neighborhood of Boone this action is very clearly traceable in the valley of the Des Moines, and in the lateral valleys of the streams that empty into it.

The old line from Moingona north was along the west bank of the river, and was on a bench cut into this overlying drift for about one and one-half miles. After a couple of very wet seasons, there was the greatest difficulty in maintaining the track along this bench. A great many different devices were resorted to in endeavoring to support the track, but it would continually be out of line at one point or another, and sometimes was rendered impassable for hours. The difficulty was finally taken care of by taking a 2x12 plank and building a lot of box drains in 16-foot lengths, putting these between the ties every 10 or 15 feet across the track and carrying them back up the slope of the hillside, with an occasional lateral diagonal drain leading into them. In a remarkably short time the water was afforded a direct means of getting away, and the movement was stopped, and from the time that this work was carried out, to the present time, we have never had the slightest trouble with the track along on that slope of the river bank.

Mr. A. S. Zinn: While I was connected with the Rock Island Road we were troubled a great deal, in Texas and Arkansas, with what we called gumbo slides; some embankments were made up of a tenacious clay, commonly called gumbo. The greatest trouble we had was in Arkansas on a line built about ten years ago. The embankments were 10 to 15 feet in height and were constantly spreading out in rainy season, where made of this gumbo soil. Mr. Molliter, while chief engineer, tried to stop the trouble by driving a row of piles close together at the foot of the embankment. The sliding continued until this piling was leaning in places

at an angle of 45 degrees. While I was down there we made a cross-section at one place which had given us considerable trouble, and where they had been putting cinders under the track; in one place there were seven feet of cinders under the track, but trouble was being experienced even then. The cross-section showed that these cinders were in a sort of trough, caused by heavy traffic gradually pushing the cinders into the embankment, and at the foot of embankment there was continual sliding. We remedied one bad place about 4,000 feet in length by spreading this embankment out to a slope of 3 to 1, then built it up with good material and placed about a foot of ballast on top. While there, I was informed by the roadmaster of the Iron Mountain Line that they stopped their slides by digging trenches, but instead of back filling with riprap they put in old ties and coal at the bottom and covered this with the gumbo soil, and burnt it in the same way they would burn gumbo for ballast. Before starting this fire they would dig trenches straight out from the track to foot of embankment, and then connect the upper end of trenches by a deep ditch parallel to the end of the ties. After the material was burned out, the ditches would be left filled with burnt clay, like broken brick; that would leave an opening for the water to get away, and in that manner they got rid of all the gumbo slides. They found this method very successful. We found that this gumbo, when saturated with water, slides down to a slope of about 3 to 1, and then stops; if you are familiar with gumbo, you know that water will hardly get through it; when very much saturated it is of a consistency of mud.

That is one of the ways we found to get rid of the gumbo slide.

Mr. Carter: How wide and how deep a ditch did you use for this draining?

Mr. Zinn: The ditches were dug about six feet deep or more, depending on height of embankment, straight out from the track, and about 2 to 3 feet wide. I suppose, however, if they had filled that up with riprap it might have answered the same purpose.

We found it a waste of money to try to drain these slides with common farm tile. We tried six-inch tiling, but found the tiling was pushed out of line and filled with mud, thus preventing the water from passing through.

Mr. H. Foster Bain, Urbana, Ill. (by letter): Mr. Merrick's account of the clay slide at the Boone viaduct suggests certain considerations regarding the course of underground water. It will be noted on referring to his very interesting detailed map and section that the disturbance took place about at the horizon where the glacial clays rest on the coal measures. This horizon is one at which wells usually find water. Despite the frequently compact nature of boulder clay, there is generally enough difference between it and the rock below to determine a water horizon. A line of springs or seepage is one of the most common indications of the horizon used in geological mapping. It is often true that the initial bed of glacial deposition was gravel or sand, and this aids

in the localization of underground water. Where such a horizon outcrops in the face of a steep bank with flat, undrained territory back of it, a vigorous flow of water is not uncommon. In this case, apparently, the actual horizon did not outcrop, being masked by the thin wash of reworked material lining the present valley. The latter was not firm enough to hold the water, nor was it open enough to allow it to pass through rapidly, and so before the accumulated water it simply sloughed off. The expedient adopted for draining the ground should afford ample protection, but the circumstance suggests the importance of providing for underground as well as surface drainage where piers must be located in such ground.

## FOREIGN RAILWAY CONSTRUCTION IN SLIDING GROUND.

E. E. R. Tratman, M. W. S. E.

Railway engineers in Europe have had very extensive experience with construction and maintenance in treacherous soil and in some cases very elaborate and costly works have been necessary. Many of these works have been necessitated by and built under peculiar and exceptional conditions, and it is of interest to put on record some of the difficulties encountered and the methods adopted for overcoming them.

### *Paris, Lyons & Mediterranean Railway.*

The Paris & Montereau division of the line from Paris to Lyons, France, was opened in 1849, and it was stated in a paper written several years ago by Mr. Cartault, one of the division engineers of that road, that for some forty years there were movements of the ground, sometimes to such an extent as to block the road. It was only by very thorough investigations as to the causes, and the execution of very extensive works, that stability was finally assured. The country traversed by the railway has a surface of loam and alternate permeable beds of limestone or sand and impermeable beds of clay, all underlaid by compact chalk. The beds are very regular and have not been subject to upheaval since their formation. The rainwater soaking into the loam flows along the first bed of clay; that and the lower beds are mainly dry, except where water is given access to them by the railway or other works. It would seem that cuts in such a formation would not disturb the equilibrium of the mass, as the surface water flows over the slopes and into the roadway ditches; the lower beds would then remain dry and stable, as the clay is only dangerous when made wet. This did not prove to be the case, however, and in a certain length of time, sometimes several years, certain slopes began to slide. This is explained by the engineers as follows: The opening of the excavation cuts the permeable beds alternated with the clay beds. The water flowing on the slopes or in the ditches wets the edges of these beds. If the beds are inclined towards the railway the water can

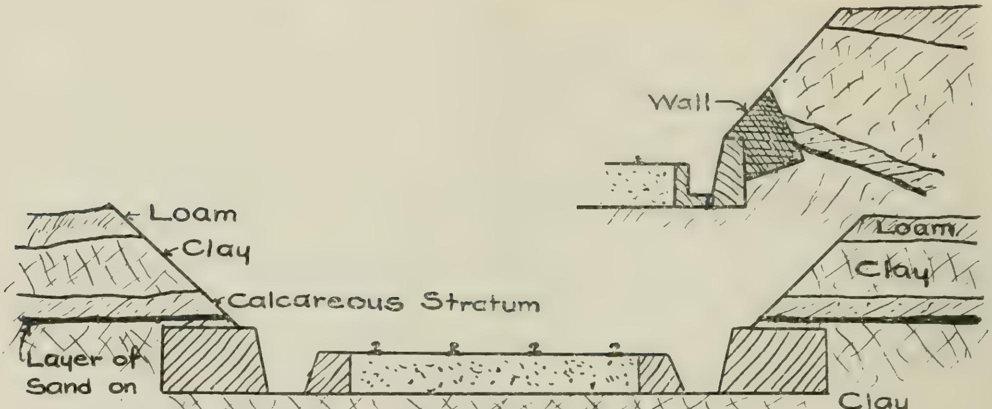



FIG. 1.


FIG. 2.

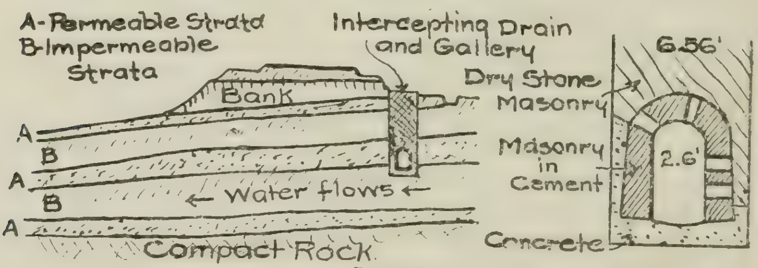



FIG. 3.


FIG. 4.

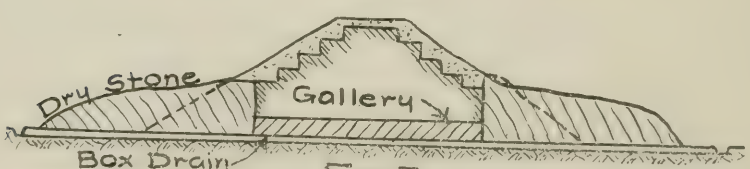



FIG. 5.

only work between them by capillary action, and causes little trouble as it does not extend to any distance, but when the slope is in the opposite direction the water gradually penetrates to a considerable distance. The slope then rests on an unstable bed, and a subsidence occurs which is increased by the vibration due to the trains, and a crack or crevasse opens along the slope, into which the rain-

water enters. Finally a mass of greater or less size detaches itself, and moving against the direction of the slope of the bed falls into the cut.

One of the most troublesome cuts was that at Mee, with a maximum depth of only 23 feet; the slopes are 45 degrees, with a toe wall of dry masonry on each side, and the ballast supported by dwarf walls to form a ditch. This is shown in Fig. 1. The cut yields a constant and considerable flow of water, even in dry seasons. Beneath the vegetable soil is a permeable bed of limestone, then a bed of impermeable clay, a second bed of limestone, a bed of sand, and finally another bed of clay on the rock. The inclination of the beds is generally opposite to that of the surface of the ground. The water flows entirely from one side of the cut, and this side has never slipped. The slides occur on the opposite side, which shows no trace of moisture. Where the bed of limestone and sand is below the roadbed, it receives no water from the excavation and no slides occur; and where the bed comes behind the dwarf retaining wall, the latter protects it, and no slides occur. But where the sliding plane is above the wall, the water of the slope gradually works along it and causes slides. Dry retaining walls carried below the ditch were of little effect, as they simply admitted water to the treacherous bed. After the causes had been thoroughly investigated, a remedy was effected by simply deepening the opposite ditch and diverting all the water on to that side. In some cases a stone wall was built to cover the edge of the permeable bed, and so prevent the water from flowing into it, as shown.

The bank following this cut is in some cases 60 feet high, and was protected by a drain formed by a deep trench filled with dry stone. But it became necessary later to build a masonry drain or gallery 5 feet high and 2 feet 4 inches wide below the level of this wall. The gallery is 840 feet long, at right angles to the railway. The head of the gallery is directly beneath the bank.

Near Senart is an arched masonry culvert which was broken into four sections by cracks parallel with the rails, due to the sliding of the beds on which the foundations were built. A masonry drain was built under the foundations, with branches forming a Y and terminating at vertical wells opening into the ditch, thus draining the lower beds and also carrying away the surface water which had formery penetrated the earth. In a number of other cases extensive drainage galleries were built to protect bridges where slides occurred and embankments, which in some cases had sunk some 10 feet below the original level, the track having been raised from time to time. Fig. 2 shows the main gallery carrying the water from a system of drains in the hillside above the railway. Fig. 3 shows the methods adopted at the bank approaching the bridge at Brolles, which had begun to slide. A trench 6.5 feet wide was built on the upper side, extending through the permeable strata, so as to intercept the flow of water. At the bottom of this was

built a masonry gallery or drain, backed by concrete on the down-hill side, and otherwise covered by rubble stone filling. Openings in the roof and up-hill wall admitted the water. The drainage gallery led to a transverse gallery or culvert passing under the bank and discharging the water far below it down the hillside.

### *Lons-Le-Saunier & Champagnole Railway.*

Another case of extensive and almost hopeless conflict with sliding ground was on the railway from Lons-le-Saunier to Champagnole, in France. As described by Mr. Meron, the chief engineer, some 14 years ago, the railway rises from Lons-le-Saunier by a grade of about 2½ per cent. to reach the crest of the first plateau of the Jura range. It cuts successively all the beds of liassic formation, which are exceptionally unstable in that district, and the situation is aggravated by the transverse slope of the hill on which the line runs, and by the presence of numerous springs. The grade has a length of about 7 miles. Work was commenced in 1881, and as no provision had been made for the drainage of the land, the work on the heavy cuts at once disturbed the equilibrium of the strata, and as fast as the movement was stopped in one place it developed at another. The banks also subsided, and in the winter of 1882-83, the ground slid into the Vertancul cut for the entire length. In November, 1884, the hill above the village of Perrigny moved bodily and completely closed the Vieux-Mont cut for a length of 150 feet. This slide was repeated on a larger scale two years later. At the opening of 1885, the three miles of line built showed nothing but settling banks and sliding cuts. Extensive drains were built around the works, and transverse trenches filled with broken stone; but the drains only worked for a time, while the stone of the ditches settled into the ground, and in a year or two the movements recommenced. The contractors threw up the work, and the engineers after long and careful investigations prepared designs for the drainage and consolidation of the land. These were approved in 1886 and the works were completed in 1888. This was done without deviation from the original line, except at the Vieux-Mont cut already mentioned, where the consolidation would have cost some $80,000 on a length of 1,300 feet, as it would have been necessary to sustain a hillside of some sixty acres, moving as one mass with a depth of from 33 to 50 feet. At this point the old cut was abandoned, and the line on the new location was thrown further out and carried over a small valley or ravine by a system of drainage galleries. This bridge naturally spanned a slide. In December, 1886, another slide occurred on an area of 60 acres, and flowed into the old cut, but fortunately the ground between the old and new lines resisted the pressure. This section of the road, 4¾ miles long, had been estimated to cost $318,220, but it actually cost $650,000, or about $136,000 per mile.

*The Lieme Embankment.*—This bank is located at the beginning of the line, on approximately horizontal ground and has a

maximum height of 41.5 feet. In view of the character of the material necessary to be used, stone mounds the entire width of the bank and about 12 ft. high were built on the ground at intervals of 130 ft. before the material of the bank was deposited. This clay was very wet, and the bank soon settled and slipped for a length of 650 ft., but without disturbing the stone drains or mounds. In order to maintain the line open for traffic, new material was deposited on the top and also on the sides to load it until the bank was in some places 200 ft. wide at the base. Fig. 4 is a section at one of these mounds. Trenches 5 ft wide, and with vertical sides, were then made across the flattened slopes of the bank and filled with stone to the level of the old drains, reducing the intervals between drains to about 43 ft. Both old and new drains were extended at the ends to conform to the actual slope of the bank, as shown in Fig. 5. Headings were then driven through the bank to connect the opposite lines of stone drains, the headings or galleries being filled with dry stone masonry, leaving a box drain at the bottom. These drifts showed that while the soil of the bank had been largely dried out there were veritable pockets of mud and water, so that in places the distance between cross drains was still further reduced to 21.5 ft. The base of the bank having been thus treated, the slopes of the upper part were cut in horizontal benches and new slopes filled in with good material brought from a distance; this was sown with lucerne and rye grass to form a heavy turf; Fig. 5. It might seem that it would have been cheaper to build the entire bank of good material brought from a distance, but it is estimated that this would have cost 70 per cent. more than the works described.

*The Perrigny Cut.*—This is a long cutting, directly following the Lieme bank above mentioned, it is 2500 ft. in length, but the trouble was mainly for about 1200 ft. at the middle, where the maximum depth was about 50 ft. The cut was first started by excavations to full depth, but this at once started sliding and caving of the ground, and it was found that the underlying material through which the lower part of the cut lay was not stable, as had been supposed. It therefore became necessary to first excavate the prism bounded by the surface of the ground, the left slope, and the horizontal plane level with the top of the right slope. This exposed a limestone and chalk formation, in which the final cut was made with slopes of 45 degrees, instead of 1-1/2 to 1 as had been intended. A section of the cut is shown in Fig. 6. This latter slope was used in the upper part of the cut, but successive slides reduced this to 1 on 2 in the upper slope on the left side, transverse trenches were cut 33 ft. apart and 6 ft. wide, the bottom being benched and having a slope of 1 per cent.; these were filled with stone, leaving a box drain at the bottom. The first of these trenches was not carried down to the good rock, but this proved to be unsatisfactory, and all others were thus deepened. During the

excavation of some of these trenches, the wet ground slid and was so soft that the trench timbering would not hold but was distorted. In spite of the severe cold weather a retaining wall of masonry in mortar was built at the foot of the slope; this was moved somewhat by the pressure, but served as a bearing for the timbering so that the trenches were at last made; these cross drains dry out the material, which would otherwise not be held back even by the heavy wall. A masonry drainage ditch was also constructed along the entire length of the top of the slope on the left side. Finally the slopes of the cut were lined with a dry-stone revetment, to protect them from the disintegrating action of the air, and acacias were planted on the upper slopes to consolidate the ground. The total cost of this one cut was about $116,500.

*Works at Conliege.*—In approaching the town of Conliege the line passes into a very unstable stratum which gave almost endless trouble. It is underlaid by schist which provides an excellent support for foundations, but unfortunately there is a bed of soft clay, full of springs between this and the surface clay, and the water from the springs saturates the surface clay to such an extent that it will not carry any load, and all the proposed embankments have had to be abandoned, after work upon one had started a slide of the whole hill for a length of 700 ft., which was finally stopped by a retaining wall carried down into the solid substratum. A drainage project was prepared by the engineers, approved by the government in 1883, and after much difficulty completed in 1885, when filling was again commenced on the bank. Two days of rain, however, started a new movement, and in one night the bank slid to the foot of the hill, pushing the soft soil below it like a wave. Still a third bank, only 8 ft. high, behaved in the same way, and it was evident that even the costly drainage works could not make the surface stratum stable.

It was therefore necessary to build masonry viaducts, with piers carried down to the solid substratum. The piers are 39.3 ft. between centers, with semicircular arches of 16.4 ft. span. The Vertancul viaduct has five arches and the Ermitage viaduct, Fig. 7, has six arches. The excavations for the piers were carefully filled with masonry, so as not to leave voids, which might start slides. It became evident, however, that it was impossible to prevent the formation of a sheet of water around the foundations, which would gradually soften the earth until a slide would occur that might carry away the piers. All the piers, therefore, had on each side a dry stone wall 2 ft. thick, carried below the base of the foundation and having at the bottom a box drain; the two drains of each span connected with a Y shaped drain, the stem of which led to a general drainage system. One of the viaducts is set with its upper side close against the hill, no parapet being used on this side, with a paved ditch outside the ballast. Beyond the ditch is a 6 ft. trench carried down to the good substratum and filled with dry stone, a

box drain at the bottom connecting with the general drainage system. The station grounds are formed by a side-hill cut, and drains consisting of trenches filled with stone are placed in the up arch down the slope, while Λ shaped cross drains between them intercept the surface water and divert it into the main drains.

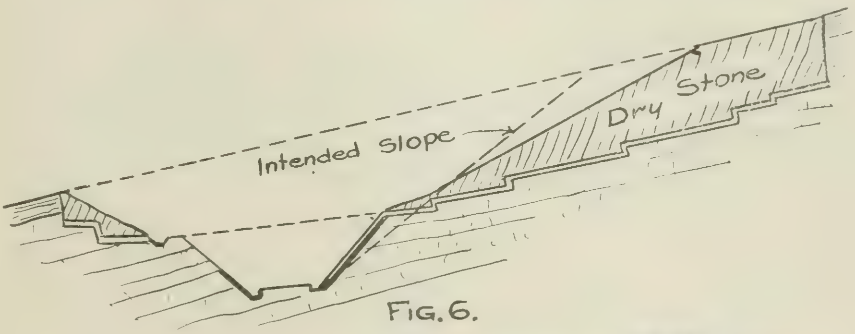



FIG. 6.

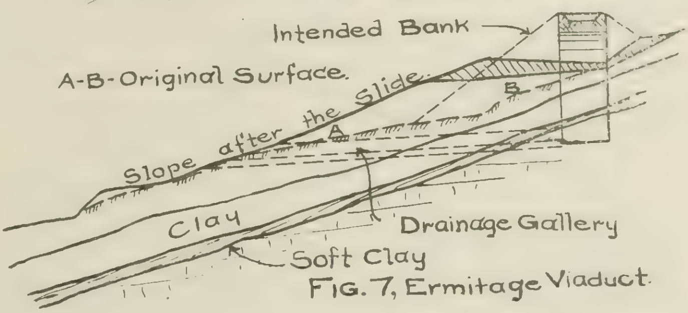



FIG. 7, Ermitage Viaduct.

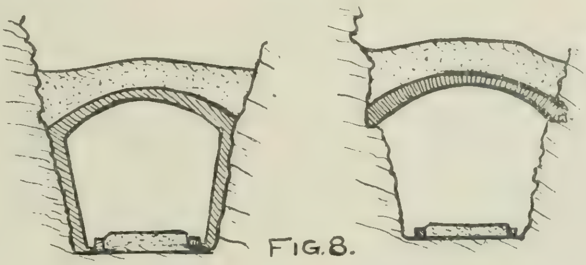


FIG. 8.

*Covered Cuts.*—In passing through rocky districts, some of the long sidehill cuts with steep slopes 65 to 100 ft. high, were subject to serious falls from above, due to the action of frost and ice. This was checked in some cases by a stone revetment of the steep slopes, but in two cases it was found more economical to build a masonry roof over the cuts. These are shown in Fig. 8. The arched roof is in one case seated in the rock of the slopes, while in the other case it is supported by inclined side walls built against the slope of the original cut, the rock being too badly disintegrated to afford support. A bed of filling above the roof protects it from falling rocks.

*The Rochechien Diversion.*—In the original location the line was intended to pass around the rocky spur overlooking the village of Revigny by a side-hill bank, beginning at the mouth of a short tunnel. The slope of the surface was about 1-½ to 1, and at the foot was a government road and the Rochechien creek. The top

of the bank was very narrow, but owing to the slope of the hill it extended far down the slope, and at one place a masonry arch bridge of 43 feet span was built across a depression. In a few months the arch was found to be cracked and the abutments moving while crevasses formed a great Λ in the face of the hill, the apex being just above the bank. The bank moved about 3 ft. out of line, and sank about 2 ft. Three deep exploration shafts were sunk to determine the actual geological conditions, and it was found that the underlying rock had a steep slope and was covered with a bed of moist clay so that there was no hope of making the bank stable. This is shown by the section Fig. 9.

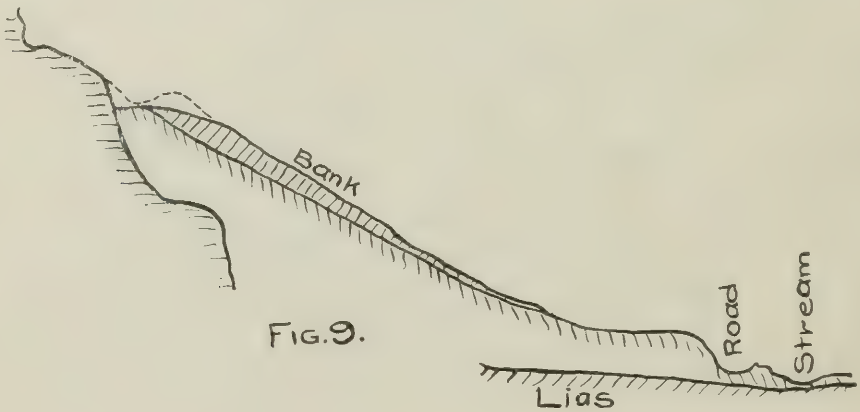



FIG. 9.

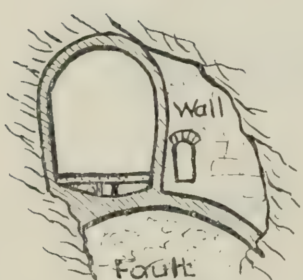



FIG. 10.

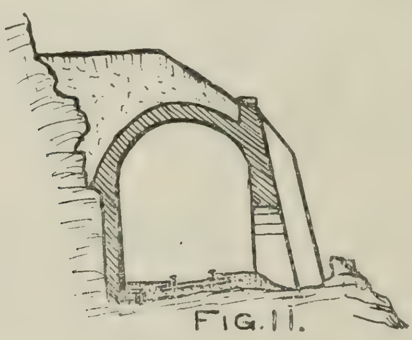


FIG. 11.

The new plan adopted was to throw the line back into the hill so as to lie in the rock, crossing the ravine filled with the treacherous material by a truss bridge supported on the rocky sides. The line was therefore continued in tunnel right to this bridge; part of this tunnel coincided with a great longitudinal fault in the rock, and one side wall had to be supported on an arch, while cross walls or buttresses were built from the side wall to the face of the rock. This is shown in Fig. 10. Beyond the bridge, the line was built partly in a masonry gallery along a sidehill cut, the gallery resembling a tunnel (but built in the open) and having arched openings in the down-hill side; Fig. 11. This diversion or deviation line cost about $54,000.

*The Albula Railway.*

On the Albula Railway, in Switzerland, very heavy mountain works were required, and many tunnels and masonry viaducts (the latter with piers carried to considerable depths) were built in preference to open cuts in steep sidehill ground where heavy retaining walls would have been required. Much of the work was in loose material overlying steep rock slopes and liable to slides. Open cuts often exposed strata of wet clayey material, very unstable, and in some cases the pressure caused this to slip, with the result that the entire superincumbent mass went with it. In most cases, rapid timbering of the style shown in Fig. 12 enabled the movement to

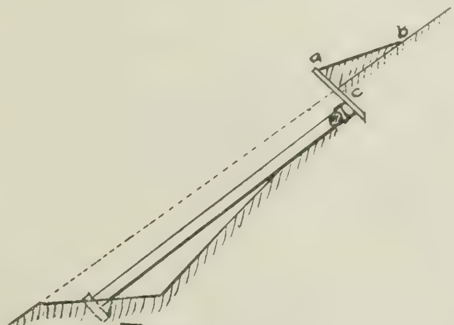



FIG. 12

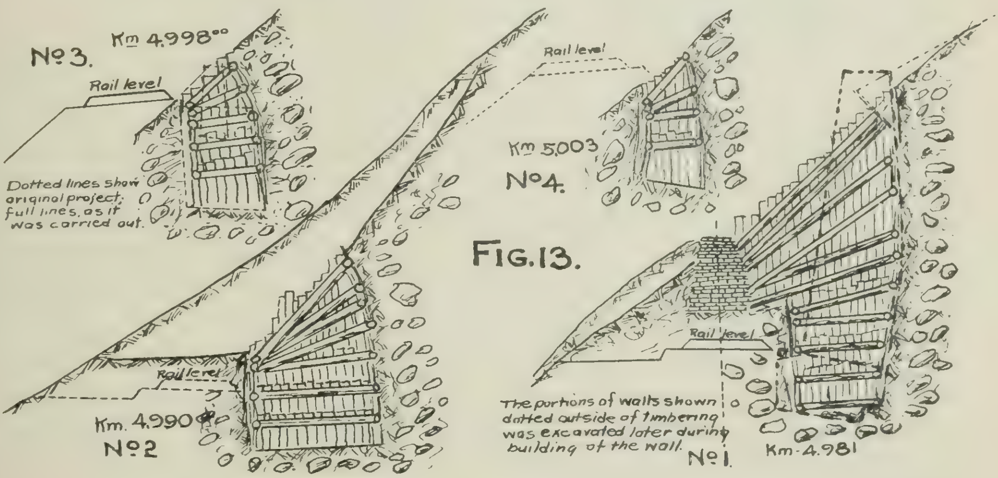



FIG. 13.

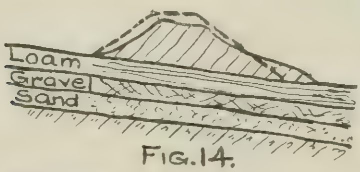
be checked temporarily while very heavy retaining walls were built, as shown in Fig. 13. In one case on the Cugneler Division, an extremely heavy wall with a face batter of 1/2 to 1 was used, having courses laid perpendicular to the face so as to aid the resistance to sliding under the pressure from behind. The wall was not carried the full height of the cut but only high enough to hold back the treacherous stratum, while the weight of the upper stratum of good material rested on top of the wall.

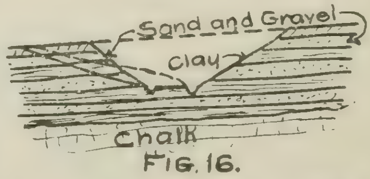
Even tunnels did not escape, however, and in the Versasca tunnel a very heavy concrete floor had to be built to prevent the wells from closing in. This floor was flat on top, and the bottom was

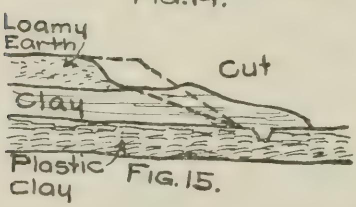
formed in a curve so as to give great thickness at the middle. When the cut at the tunnel portal began to slide, timbering was put in and held it until a heavy retaining wall could be built.

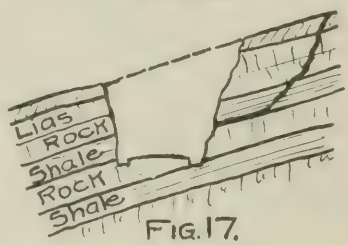
*Miscellaneous Cases.*

The relations of geological conditions to certain forms of slides are described in a recent paper on "Geology in Relation to Engineering" in "The Engineer," of London. Fig. 14 illustrates a case where a railway embankment on side-hill ground was undermined by the surface water flowing down the hillside, so that the bank slipped bodily, and at the same time spread out at the base. This was remedied by cutting a ditch parallel with the upper toe of the




bank and then tunneling through the bank for culverts to carry the water to the lower side. It is stated that with the strata shown, the bank would hardly have been expected to give way, as a large portion of the water would naturally soak away into the ground, while the probability of a collapse would have been greater if the surface had been of a rocky nature. It is most likely, however, that the loam became so saturated as to be unstable and unable to carry the load due to the bank, as in the case of the French railways noted above.

Cuts which are apt to be very troublesome are those passing through clays which are apparently very stiff when dry (or nearly so), and will stand at slopes of 1 to 1, or 1-1/2 to 1, when freshly excavated, but which turn almost to mud after being exposed to the air and weather for some time, and will then only be stable at slopes of 3, 4 or 6 to 1. The only alternatives are (1) to use a flatter slope (which may require the purchase of more land); (2) to excavate a large portion of the slope, burn it like clay for ballast, and then replace it; or (3) to drain the slope by cutting trenches in the face and filling them with stone, afterwards forming the cut to its original or a flatter slope, if possible. The way in which the sides of such a cut will slip is shown in Fig. 15.

An instance of a slip in a cut on a German railway is shown in Fig. 16, and shows the action of a slide against the inclination

of the strata, as in a case on the Paris, Lyons & Mediterranean Railway, already described. On this German line, the cut was through sidehill ground with alternate layers of sandy gravel and clay. The surface drainage after heavy rains passed down the slope on the upper side and into the track ditch without doing any damage. On the lower side, however, it percolated through the strata until they were so saturated that masses would slide into the cut, as shown by the dotted lines. In some cases it required forty years for this result to develop. Cuts through sidehill ground in such formations as the lias, which consists of alternate strata of rock and shale, etc., and which strata may dip at a steep angle, should be carefully watched for landslides; these are very liable to occur, especially after hard frosts, rain and snow. The water penetrates the fissures, and by its freezing and swelling disintegrates the shale; the result is that the rock, losing its support, and shaken by the vibration due to passing trains, breaks away and falls into the cut, as shown in Fig. 17. During the excavation of such a cut, the dip of the strata should be measured and plotted as a cross section, so as to show if trouble of this kind is likely to occur.

An extremely interesting paper on certain properties of clay as related to the occurrence of slides was presented before the Canadian Society of Civil Engineers in December, 1902, by Mr. H. J. Cambie, and is worth noting here. It appears that clay which is perpetually moist will absorb only a certain further percentage of water, and will retain its form and consistency. But if dried out and then again subjected to the influence of water it will absorb a greater percentage than the normal, and will then turn to mud, having no cohesion. In a certain portion of British Columbia the rainfall is very light and the water penetrates only a few inches, being dried up by the rapid evaporation. The Canadian Pacific Railway cuts in the dry clay were very stable, the clay being hard and resembling soft soapstone. But when irrigation was introduced in that country, landslides began to occur along the railway, and investigation showed that under the influence of moisture the hard, dry clay lost its cohesion. In the tests, a block of the dry clay was placed upon a plate and water dropped upon it: it absorbed 50 per cent. of its own weight of water without any change of form or other visible effect, but when it had absorbed about 60 per cent. of water, it completely collapsed and became as fluid as water. An English writer states that sandy clays, weighing 113 pounds per cubic foot when dry, will readily absorb water and turn into a sludge with an angle of repose not exceeding 16 degrees. "Argillaceous silt will absorb 53.5 per cent. of its volume without altering its form, but after absorbing 78.5 per cent., it disintegrates and becomes a slurry. Blue lias clay will often not stand at slopes of 4 and 5 to 1, when saturated with water, and plastic clays at slopes of 7 to 1."

It has been suggested that tile may be economically used in land drainage work of the kind referred to, but it is evident that it would be of little use in such treacherous soil as that encountered by the French railways mentioned. A very slight movement or slip would dislocate and disconnect the drains, rendering them useless. With the stone-filled trenches, however, considerable distortion may take place without interrupting the continuity of the drain. On many European railways considerable trouble has been experienced from slides in wet cuts and in wet lands, and the use of drains formed of trenches filled with stone is very general. In all the cases mentioned, the aim has been to secure permanent stability and safety, and not merely a temporary relief.

# "SCHOOLS, ENGINEERS AND EMPLOYERS"

PROF. P. B. WOODWORTH, M. W. S. E.

*Presented before the Electrical Section, March 16, 1906.*

A great many electrical graduates take subordinate positions with people engaged in the construction, sale, erection, or operation of electrical machinery. The value of the graduate to his employer and his personal advancement depend largely upon his technical education. The greatest good to all concerned should be obtained by a thorough understanding between the employer and the technical school.

The technical schools now look to the employers for suggestions and friendly criticism, as a basis of future advancement in the education of the engineer.

It is easy to recall the time when a technical education was counted rather against the man who applied for work with a manufacturing company. Charles F. Scott in 1903 read a paper in Chicago in which he said: "In the past dozen years a very great change has taken place in technical graduates, both as to quantity and quality. There is also a change in the estimate of their value and practical work. Now the output of the electrical courses of our technical schools is not equal to the demand." While Mr. Scott's statement may contribute to the already monumental cocksureness of the technical school professor, it indicates that times have changed, and that the employer and the technical schools are on speaking terms.

Mr. J. G. White, of New York, says in his paper on "The Problems that are facing the Electrical Engineer of today, and the qualities of Mind and Character which are needed to meet them": "People are today looking for engineers, and would gladly pay salaries of six to ten thousand dollars per annum for men of exactly right qualifications."

It would be easy to find men who have had all the necessary technical training. The questions asked of a man, however, are such as these:

"Has he good business judgment?
"Has he tact?
"Has he mental capacity?
"Has he breadth to develop into a big man?
"Is he diplomatic?
"Has he ability to negotiate?
"Has he initiative without being erratic?
"Will he get results?"

From the context this is evidently a list of the graduate engineer's deficiencies. But can they be charged to the technical school? At the best, the technical training covers only a few years, and the

school has to take the pupils who come to it. Personal observation leads me to believe that to meet this list will require a training which will cover not less than two generations, *counting backward.*

Merely casual observers would limit the practical training given in a technical school to the shop and laboratory courses. Employers often say "give less shop work," or "give more shop work." We should be pleased to have employers get together on this point, and in the meantime we ask: "Would you give less than is required at Massachusetts Institute of Technology, or more than is required at Cornell University?" Less than the Massachusetts "Tech." means practically nothing; more than "Cornell" means practically nothing else; yet both institutions are of unquestionably high standing. Again, some employers ask for skilled shop workmen. I have yet to know of any technical school where they even pretend to turn out such men. The effort is to give the student that respectful familiarity with the shop which will make apparent the possibilities and the limitations of machinery. The young engineer should be so trained that when he comes in contact with the shop foreman he will be able successfully to co-operate with him.

The laboratory courses have received and merit more criticism than any other part of the technical course. Here a great amount of latitude must be allowed to fit circumstances. Laboratories with equipments of the penny arcade type are condemned; they always have been condemned and always will be. But there are places and times where that is the only type of laboratory that is workable. Then there are the so-called research laboratories, where every student is on an independent voyage of discovery. The student hitches his wagon to a star, and not one in a million ever succeeds in pulling in his leading string. Any laboratory course which does not take into account maturity of the student, his previous training, and the final result is a failure. Did you graduate ten years ago? If so, it is more than probable that you know nothing of the present methods in vogue at your alma mater.

Mr. L. A. Osborne, of the Westinghouse Electric Manufacturing Co., speaking of the proper qualifications of electrical engineer school graduates from the manufacturer's standpoint says:

> "The work of modern engineering has resulted in the development "ment of enormous industries, requiring skill, intelligence, "knowledge, and a high order of administrative ability, which "were entirely unnecessary in the days of small shops and "limited organizations. It has followed that the problems in-"cident to this great industrial development have been more "than the limited education and intelligence of the old-time "shop superintendent could cope with."

But to meet this new order of things, he finds that the technical schools are not doing their duty, because, first, graduates consider manufacturing unattractive; second, shop work they find not highly specialized; third, they are ignorant of work organization; fourth, they lack knowledge of works accounting; fifth, they lack knowledge of eco-

nomic laws between laborer and employer; sixth, they have hazy notions of the law of contracts.

> "Our technical schools today, (he continues), are ad-"mirably fitted to turn out men who are well grounded in the "fundamentals of engineering. As a rule they are good "mathematicians, electricians, chemists, and physicists, and "they have all technical groundwork for pursuing the pro-"fession, but they are as a class wofully lacking in compre-"hension of many of the subjects which are inseparably "connected with the practice of the profession."

What Mr. Osborne says relative to the sufficiency of training given the technical graduate is more than we expected, and more than we have ever believed, or ever hoped for. As to his additional requirements, skilled workmanship, political economy, practical ethics, shop accounting, and the laws of contracts; the first of these has never been attempted, the next four are practically unknown in technical courses, while the fifth is now given in most technical schools.

When a practical man tells us about the work demanded of the men after they graduate, and of the attitude we should teach the student to hold toward his future engineering work, then he gives us something which we very much want to know. An exceedingly able paper by E. B. Raymond on a proposed reform in technical education gives us just this kind of information and proposes a remedy. Mr. Raymond's paper is especially interesting to me because the proposal is exactly in line with the work at the institution where I am now employed. Mr. Raymond proposed a solution of what a large number of writers have called "the great problem," viz., how to do ten years' technical work in less than ten years' time. His answer is: "Begin right; begin in the high school, and eliminate the enormous waste which occurs in the transmission from the high school to the technical school." The boy who is to be an engineer should be under one direction during the whole period of adolescence. His work should be definite, coherent and without waste. All the fundamental work should be under the guidance of the engineers who are later to teach him mechanics. A boy of good ability should enter such a school at, say, 14, and graduate at 21. By so doing he sacrifices much of what is called a general education, but he attains a high degree of technical efficiency at an early age; twenty-one is the earliest age at which a man may call himself an engineer; and even then it remains to be seen whether he really is an engineer. When at the very beginning of his course the student learns that the business of education is to develop not a dreamer but a worker; that it takes work to become an engineer, and work to maintain a position as an engineer, and more work to accomplish anything, then and only then is his success in any way assured.

In this review, I began looking for the utterances of modern practical men, other than technical school graduates, who are on record

as critics of the present technical school methods. It soon became clear that there really had been a great change, either such a man has ceased to exist, or he has not contributed from his experience for our information and assistance. It appears that the modern practical man *is* a college graduate, and as such he feels called upon to express himself with high appreciation of our American engineering schools and with warm regards for their graduates.

There is one critic of the technical school who is the most valuable source of information. I refer to the graduate, who has been out two or three years trying to discover if he really is an engineer. It has been my good fortune during the past seven years to know intimately, through personal work, over 150 such men, who are now, or have been, students in the post-graduate classes at Lewis Institute. They came from Maine, Massachusetts, Connecticut, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Kentucky, Tennessee, Wisconsin, Iowa, Minnesota and Nebraska. To a man they are fine fellows and loyal to their schools, but they are practically a unit in one caustic criticism on their engineering course. They find a lack of coherence, an immense waste of time and energy, due to what John Perry, the English engineer and educator, has called "the tin can education." One of these graduates in his analysis of the situation used an illustration which I have never forgotten. He had taken a course in electrical engineering, had studied arithmetic, geometry, algebra, physics, trigonometry, analytics, electricity, thermodynamics, calculus, and the steam engine. And it fell out, as it often does, that his work was with steam engineering. He had heard of constant values in arithmetic, had equal area problems in geometry, and problems where A B equals a constant in algebra; had Boyle's law, the law of capillary attraction, and several other laws of the same kind; had the *equilateral hyperbole* in analytics, and the *isothermal* curve for the steam engine, but it took him about two years to discover that they were all the same thing and stood for the theorectical curve which he should have obtained on the steam engine indicator. Now, so far as the technical school is concerned, this critic, the technical graduate, is the real employer. He employs the technical school, gives his time, money and energy, and has reason to expect a sufficient and practical training. The most hopeful sign of progressiveness in a technical school of today is shown when managers, directors and instructors all give an attentive ear to this most important employer. Every good engineering school now keeps in close contact with its own graduates to conserve its own best interests.

Every member of the Western Society of Engineers ought to be interested in a paper which covers this entire field of both friendly and hostile criticism as I have heard it from engineering school graduates. Such a paper has been prepared by a master hand. The paper refers to what Professor Perry called "the tin can goods", under the name of "The Step by Step Method." The paper also discusses a great number of the mistakes of the past and

the causes for future failures of the technical schools not here mentioned. Every man who is at all interested in technical education, whether school man, engineer, or employer, should use this paper as a manual. If you wish a copy write to Mr. Ralph W. Pope, Secretary, A. I. E. E., New York, for the presidential address delivered at Great Barrington, Mass., 1902, by Charles P. Steinmetz.

DISCUSSION.

*Mr. McMeen* (chairman): We are here tonight to discuss the old question of the relation of the technical school to manufacturing and other technical institutions. It is likely that those of us who are here tonight are too much of one mind to produce a discussion which will be sufficiently argumentative. I do not expect that we shall be able to settle the question for all time; it is a question of condition rather than of opinion. Nevertheless we shall no doubt be able to elicit some new thoughts.

I will say that we would like to have each one here think of the questions, as presented, and if he agrees with each and every statement made, say so during the evening, or if he does not, will he please show Professor Woodworth wherein and why he differs.

*Mr. H. R. King:* While Prof. Woodworth was reading his paper I was turning over in my mind the conditions under which we are working at the Hawthorne plant of the Western Electric Company. One of the questions that I always put to the young student is this: "Do you really know where you want to land? What are you after? Are you planning to be a constructing engineer, shop engineer, designing engineer, sales engineer, or what?" I am unable to recall any student I have ever talked with who really appreciated that there are these various types of engineers. He thought an engineer was an engineer, and that that was about the limit. The employer ,of course, to make the most use of the student's ability must know what he is aiming for, and I think that is one of the points that should be brought out in this college course; that is, to bring him up to the point of thinking what he is after,—just what he is after,—and to guide his work, as much as is consistent with the regular order of things at the college, along the channel in which he wishes to work when he gets out. It is a comparatively simple matter for the manufacturer, if he knows that the young man is working for some end to assist him along that line. We have recently inaugurated what we termed a one year course at our factory. We look on that course as an extension of the education of the student as much, I think, as the high school work should be looked upon as the beginning, and we plan to place the young man in the various departments of which the entire organization is made. Before we place him there, however, we try as hard as we can to line him up along some definite position; that is, whether he has sales engineering ambition, or constructing, erecting or operating engineering ambition; and we endeavor to educate him, during that year's work, for that particular thing. We have

no thought of profit for his services for the year. We look for our profit in employing him after his course is finished. Our task would be much simpler if the young man really had fixed ideas as to his future beyond that time.

Referring to the eight questions mentioned in Prof. Woodworth's paper, the last one,—"Will he get results?"—it seems to me that includes all the others. If a man gets results it would seem as if he must necessarily have the other qualifications which answer for the other questions. The manufacturer, of course, looks upon the results; he is not especially interested as to whether a man is a diplomat or a lawyer, but the *results* are the things to be considered, and it is to that end that a student must of course be educated, not only in college but for the first three or four years after he leaves college. I do not believe a young man who becomes an engineer at twenty-one years of age should consider himself an expert. An old college professor told a classmate of mine at one time that the world was not ready to receive a man's opinion in engineering work until after he was thirty years old; that his work; up to that time was looked upon as purely educational. Perhaps in these days of rapid advancement the age might be shaded to 28, and, perhaps, fifteen years from now, to 26; but when a man graduates at the age of 18 to 21, he certainly cannot be considered an engineer until he is 30; he is only an engineerig student.

*Mr. McMeen:* As I understand you, Mr. King, about the first thing you do, in talking with a newly graduated engineer, is to enquire where he thinks he wants to land, and you are surprised to find that generally he does not know; but you think he ought to know by then,—that he should have begun making up his mind?

*Mr. King:* Not necessarily.

*Mr. McMeen:* This young graduate did not know there were so many kinds of engineering until you told him. I wonder what you would like to have him do in order to come to you prepared, as to his mind, in that regard? I am wondering also if there is not a responsibility on you to assist such young men to find themselves?

*Mr. King:* The idea is this: The training of students for these various branches of engineering should be about the same, but the young man should know what he wants, in order to better give the manufacturer opportunity to guide him after he leaves college. After he leaves college, his training in his work should be according to his ultimate aim, and it might be varied during the last year of his college course, that is, if he thought he wished to be an engineering salesman, his reading might be guided in that direction. That, of course, might come of itself if a man had his ideas fixed. This work need not necessarily be done in college, but his outside reading should vary with the ideas for his future work. Not that his work should be different, should he specialize, but that he should have fixed ideas, which, of course, might be changed if he saw he was mistaken. But he should come to the maunfacturer with some fixed idea of what he wants to do, the same

as an experienced man comes to a manufacturer and wants a job; he does not say, "I want a job,—anything from president down to watchman;" he wants some particular job. I believe the engineering student should come in the same way. He should say: "I want to be a constructing engineer, a designing engineer, or an operating engineer," and the manufacturer should train him to fill that kind of a position, and it is only in that way the manufacturers can afford to spend their time and money for a year or longer training the young man to fill some particular position.

*Mr. McMeen:* We would like very much to hear from anyone who is within hailing distance of his own university days, and can remember enough of what part of his present knowledge he gained there, to point out shortcomings.

*Mr. Howlett:* I am going to take a few exceptions to what our friend, Prof. Woodworth, has just presented to us, so as to get up a little argument. If there were no disagreements this would be an uneventful world.

As long as there are employed and employers, there will always be complaints, and strive as we will they will never ge obliterated. All of us, whether we be employed or employer, are endeavoring to do *something* better and at a less expense than the other fellow. If an employer ceased to complain he would be going backward, and would soon be removed by his superiors. My review of the subject will not be with a hope of adjusting the claims of the employers, as this is hopeless. I suppose bringing up a matter that is nearer home and of material benefit to ourselves as individuals. The subject matter is not new. I am taking the most of it from a paper which I read before this Society last year.

> "The average college-bred engineer receives a very thorough "training in a large variety of engineering studies, arranged in "carefully planned courses by learned professors. The object "being to train the mind to enable the graduate to tackle and "successfully solve engineering problems. But unfortunately "the average engineer receives absolutely no training in the "development of the mind or in any other way to enable him to "secure the opportunity to solve the problems. If shortly after "graduation, with finishing touches in some large factory, the "embryo engineer starts into business, he is confronted with "the very perplexing problem of how to secure the contracts "for his services. This requires a knowledge of selling. He "will find a number of experienced men after the same con-"tract, and he will realize that before he can presume to have "the standing in the profession of his senior competitors—he "must have carried to successful completion a number of con-"tracts. But how is he to secure them?
>
> "Many young engineers in this predicament find that it is "necessary to spend considerable time, to obtain by actual ex-

"perience a knowledge of the commerical phase of their pro-"fession.

"Would not our engineering school training then be much "more complete and a great deal more beneficial, if it embraced "studies that would give us the benefit of the successful com-"mercial side of the profession, as well as the purely engineer-"ing? Why cannot we be taught in our engineer-"ing studies to take advantage of the experience of the *success-"ful salesman?*

"I believe we can, and would suggest the following remedy:

"All professional schools should incorporate in their senior "year, such studies as would develop the mind in a manner "would help him to profit by the experience of others in secur-"ing an opportunity to perform the work that his professional "training enabled him to handle.

"If such studies be introduced, I believe it would materially "increase the efficiency of such schools and materially improve "the standing of professional men. It is particularly noticable "of the successful men, those with the professional training "are the most powerful.

"Some will ask, 'What will the studies be?'

"In lieu of text books, lectures could be given in the senior "years, on the following suggestions for topics:

"1.—'On the essentials to be kept in mind when approach-"ing a stranger for a purely business interview.'

"2.—'Many ways of securing attention.'

"3.—'Arousing an interest in your proposition,'

"4.—'Securing material for a persuasive talk.'

"5.—'The elements of talking convincingly with logical ex-"pressions.'

"6.—'When to talk suggestively rather than argumentatively.'

"7.—'On the elements of a successful impromptu address be-"fore an assemblage, such as a Municipal Council or State "board.'

"8.—'On arguing a point successfully.'

"9.—'On the admission of an interruption or an objection.'

"10.—'The treatment and overcoming of self-assertion,'

"11.—'The proper method of criticising competitors' argu-"ments.'

"12.—'Proper manner to assume in addressing the essentially "serious and also easy-going, pleasure loving type.'

"13.—'How to successfully create desire.'

"14.—'Auto suggestion: its commercial possibilities.'

"15.—Choosing the most successful time for an interview and "the consideration of the proper time to discuss the matter of "terms.'

"16.—'Points to be avoided in closing a business arrange-"ment.'

"17.—'On the relation between character building and business getting persuasion.'

"18.—'The influence of suggestion upon the human mind, "with special reference to its commercial possibilities.'

"Such subject matter is capable of almost endless expansion.

"The following advertisement was taken from a recent copy "of a Sunday newspaper, which brings out the point that the "average engineer, while capable of handling engineering work, "is usually very deficient in securing it to handle.

" '$50.00.

" 'Young C. E. and surveyor, with first-class references and "8 years exp. on R. R. location, construction and maintenance, "will pay above amount for assistance in securing immediate "employment. Address in strict confidence,

C——, Tribune Office.'

"It will be seen from the above that the young engineer has "a *degree* and eight years experience in engineering work, and "yet is not successful in selling his services. Had he received "the training suggested, he undoubtedly would not find himself " in this predicament."

Mr. W. B. Hale, offered the following remarks in discussion of my paper at the time it was presented:

"In all great engineering enterprises we see at the head the "executive officers—which is at it should be; next come the commercial men, and finally, away down at the bottom, at least so "far as salary is concerned, we find the engineer. The question therefore arises, why should the man who *sells* the dynomo, receive a larger compensation than the man who designs "it? Does the trouble lie with the engineer himself, or is it, "that his education is at fault? Is his training so technical and "so elaborate that he leaves college without a clear idea of "the commercial basis upon which engineering to be successful "must rest? Is he too familiar with the molecular theory and "too ignorant of human nature?"

Also, "I noticed in this month's number of the Engineering "Magazine a review of a recent address delivered by James "Swinburne before the students of the British Institution of "Electrical Engineers, on the subject under discussion this evening. He said that he would define the present status in this "way: the business man at the top, the practical engineer or "sales engineer in the middle, and the technical engineer or "pure scientist at the bottom. 'I do not call them pure scientists, however' he added. 'I call them 'raw' scientist.' It "occurs to me that the *raw* scientist, after he emerges into "practical life, very soon becomes a *cooked* scientist, because he "is apt to be continually in hot water."

I hope that this paper will develop an interest in those having in charge the planning of the courses in our technical schools to such

an extent that they will incorporate some of the studies that would assist the embryo engineer in selling his services to the best advantage. The value of our services to ourselves and everyone else naturally increases with experience. But if we cannot get work we cannot get experience, and that brings us to a standstill.

*Mr. McMeen:* This paper of Mr. Howlett's was presented before the Society January 13, 1905, and it makes an admirable response to the subject we have tonight. I am very glad indeed that it has been recalled to our attention. I knew of the paper only by title, and it bears evidence of being well worth not only of re-presentation here, but of re-study, to make surer of these things from the standpoint of his analysis. I know that those situated like myself must have realized the very great value of salesmanship in connection with the product which they have to offer, if they are engineers. I think I had been an engineer for fifteen years before the glimmer of an idea came to me that salesmanship lay anywhere near me. I was really quite ignorant of goods made by competitors; a knowledge of a competitor's product is a necessary thing in our lines of salesmanship, and many of us are quite innocent of this fact.

*Prof. Freeman:* (Armour Institute). A distinguished painter was once asked by a visitor to his studio "How do you mix your paints?" "With brains, madam, with brains," was his reply.

If one were to answer the inquiry "What constitutes good engineering" in the same manner, he would be tempted to say, "Good materials tied together with clear thinking."

The subject under discussion this evening is of special interest, on account of the rarity with which such topics come up in society like this.

It is my understanding that the average engineer is quite frequently called upon to use his head—occasional circumstantial evidence to the contrary notwithstanding. Furthermore it is a matter of common rumor that he finds use for nearly all of the thinking ability of those who are working under his direction. To restate the proposition, the mental ability of the working force at his command is of as much importance to the engineer in charge as is the mechanical integrity of the machines entering into the work.

Associations of engineers generally have devoted their energies to the study of materials and machines with an occasional look over the shoulder at the brain mills, accompanied by a feeling of wonder mingled with pity for the inmates.

As most ably pointed out this evening this is not as it should be. The teaching in the lecture room and laboratories should have the benefit of the experiences and opportunity of those who are in the engineering field proper. On the other hand the practising engineer should acquaint himself with the limitations under which his brothers labors enter that he may not expect too much on the one hand and may make useful suggestions on the other.

In regard to the scholastic training of the young engineer it must be borne in mind that the preparation which the vast majority of

them possess when they enter the average technical school is that afforded by the high schools and academies. In four short years, of less than nine months each and a five-day week, the average technical institution is supposed to be able to acquaint these young men with not only the principles but many of the practices of their future vocation. From present indications our tendency is rather to shorten than lengthen this time. The only means, therefore, which are left the educators are those which will render his methods more efficient, which will enable him to eliminate that which is unessential or of transient importance and to study those features and employ those means which experience shows to be of lasting importance. Personally it is my feelings that if it were possible to express in a single sentence the object of a course for engineers it would be *"A course of study which inculcates the ability to think straight."* Young men who are loaded down with a lot of practical wrinkles—who have spent their time becoming familiar with the concrete examples of a specialized class of machinery generally find that when the time comes for them to have an opportunity to make use of this particular knowledge that that class of machinery has so changed or practice has so altered that their specific knowledge is of little use.

If the members of this audience will carefully review in their own minds the specific things which they learned in college and compare them with the things which they need to know and do know, I am inclined to think that they will agree with my contention that the concrete contribution to their engineering knowledge of their college career represents a ridiculously small part of their working capital. But there is one feature which their college training has given them which is of paramount importance, and that is their ability to reason from cause to effect,—their ability to apply fundamental principles for varying conditions; in other words their ability to think straight.

Referring again to the advisability of useful suggestions coming from those in the engineering field, I would ask, who among this audience has ever written to his former instructor in Engineering, telling him wherein the course might be improved. Friendly criticism based on realizable things is what is needed. Pleasing compliments are encouraging but they seldom remove faults. Your interest in the proper preparation of the young engineer is just as vital, and just as profitable as your interest in the material means of engineering, if you are seeking that larger success with which we all hope to round out our days.

It occurred to me, while Prof. Woodworth was reading the J. G. White specifications, that a man that would fulfill those requirements would make a most successful Insurance President, and would not need to work for $10,000 a year. In regard to the other question, that of co-ordination of effort, undoubtedly the young man who knows what he wants to do should have his training begin early. I have had a personal experience along that line, which it

might be well to relate: I graduated from a general scientific course at the age of twenty-one, and I remember clearly to this day the feeling of utter lonesomeness and "lostness" I had the day after graduation, as to what I should do in life. I was prepared for almost anything in general and nothing in particular, and I found the majority of my classmates were in the same predicament; some were determined, owing to social relations, to get married at the earliest opportunity.

But the question of a young man finding himself must be based largely on experience, and Mr. King, when he asks for a determination on the part of a young man to follow a certain line of engineering, fails to recognize, as was indicated by the question of our esteemed Chairman, that he has never given that young man any experience; has never given him an opportunity for experience; has presented to him probably for the first time the fact that there are these various lines of engineering. With that lack of knowledge how can you expect a determination unless you have a genius in the man that is not to be suppressed?

As a matter of fact, I think the average instructor will be able to predict quite closely the general line of endeavor in which the young man will make a success. I understand from Mr. Rohrer, of the General Electric Co., at Schenectady, N. Y., that it is their practice to watch the young college men in their employ, and, from the general tendencies they manifest in the work throughout the various parts of the factory, to finally suggest that they follow the particular work where their tendencies have been manifested. I know that among our students at Armour Institute there are frequently pronounced tendencies for certain things; for instance, one student will be seen to have a pronounced motive temperament; some students we know should be operating enginees; other studnts do not care particularly about mere moving things, but are deeply interested in the theoretical principles of design, and they gradually drift into those things. But after observing the characteristics of these young men one soon gets to be in a position where he can make a very good guess of the line of work they should follow, and often I have taken upon myself to suggest to such an individual that he probably will make a success in one line and a failure in another.

While Mr. Howlett was speaking I recalled an experience of my own. In connection with a course in pedagagy our professor gave a course of lectures with the idea in view of preparing those who were to become teachers for the problem of "tackling" school boards and various similar employers. He gave a large number of usable and in some cases interesting methods of approaching these people. He instructed them how to get on the good side of "the lady of the house," who would be the ruling member as far as influence went. I have found occasion to apply that idea in my talks, especially to the senior class and have asked them to study the habits of the successful book agent, or the successful insurance agent. I have suggested that they do not turn these fellows down but let them talk.

and see wherein they impress favorably, making use of this experience to their own advantage later on. It seems to me that by careful study of such points as these, a young man can learn a great deal about how to present himself to the best advantage, and how to get the best market value for his services.

*Mr. K. B. Miller* (by letter): It is with great regret that I cannot be present at the meeting to be held tonight, as the subject to be discussed is one that I believe to be of very great importance, and one also in which I happen to be very much interested personally. Finding at the last moment that I cannot be present, I take the liberty of jotting down a few thoughts, although of course I have had no opportunity to find out what Prof. Woodworth has to say in his paper.

The announcement states that employers in general have criticised educational institutions for not giving *practical* courses of education in technical subjects. I take issue squarely with this view. If I were to criticise the technical schools of this country as I know them it would be rather on the ground that they are too practical, and that they result in a lop-sided development of the individual.

This demand on the part of employers for a more practical lot of graduates is, I think, a short-sighted policy; and were the demand made by the students it would be even more short-sighted on their part. As the student is the man most vitally concerned, I will consider him first. The line of education in school which will enable him in the long run to become the best citizen in the broad sense, and to get the most out of life, is, from his standpoint, the best. If during the years while he is in college or school, he neglects the broader field of education for the narrower technical development, he is likely to become a wooden man. He is likely to so stunt his intellectual development that when in after life really broad problems arise he is totally unable to solve them because unable to even comprehend the task that is set before him.

The employer makes a mistake, in my estimation, in demanding an undue amount of practical knowledge on the part of the college graduates. My own experience as an employer of technically-trained college men leads me to believe that the graduate trained in practical directions to the exclusion of a broader training, may be of greater immediate value to his employer than his more broadly educated brother; but that the broader man will in the course of a few years, be of very much greater value to his employer on account of his greater fundamental knowledge and consequent ability to grapple with larger things.

I believe that our technical schools should sacrifice something of the purely technical side of their curricula, if this is necessary, in order to give the student a certain amount of knowledge that will enable him to connect his own particular calling with the callings of his fellow men. Engineering problems are becoming more and more complex. The engineer is now called upon to deal not only with forces and

material things, but he must deal with problems of business policy, of economics and of social conditions. As a training for this, are technical schools to teach him the proper dimensions for the thread of a 2-56 machine screw?

I believe that the student should have a more thorough ground work in the sciences broadly; in history, and in social and political economy, even though this be secured at a sacrifice of some skill acquired in the handling of tools and in other so-called practical lines of knowledge.

There is another demand, sometimes made on the part of employers, which after all does not differ very widely from the demand for more practical men. This is the requirement that the universities shall turn out specialists in various lines of work. I think that the technical courses in schools and universities are already specialized to as great a degree as desirable. If a student wants to qualify himself for some specific and narrow branch,—of electrical engineering, for instance,—let him specialize in this branch by doing additional work during his regular course, or by post graduate work; and under no circumstances let him attempt to specialize until he has been thoroughly grounded in the more general subjects of that field of engineering in which he intends to practice.

*Mr. DeWolfe:* When I was a small boy, attending public school, a parent complained to the Superintendent that his daughter was not getting along as he felt she should. The reply was, "we are supposed to furnish instruction but we cannot furnish the brains," I believe the technical school always has been and always will be blamed for unsatisfactory results naturally rising from that very condition.

As Prof. Freeman has said, four years of five days a week is the average high school course, and there can be just so much taught in that time. When we begin to discuss the work of the technical schools, whether they should do this or whether they should do that, it all comes down to the point,—is the student given all he can do now? If he is, what will you cut out when you bring into the schools this new matter?

I believe the student should as nearly as possible, either upon his own initiative or by the advice of the parents, select a school which will give the desired results in the line he wishes to work out. A boy of 17 to 19—which I believe is the usual age for leaving high school and going to college—in the affairs of the world is naturally a youth. When I was ready to go to college, this matter of the selection of a school was rather a difficult one. My father was a retail merchant in a small town and wished me to follow that line of working; he was entirely out of sympathy with my desires for an engineering education. Fortunately I received advice from competent engineers. A Government engineer on marine work in Lake Michigan, when I told him I had finally decided to study engineering said, "Well, the country is full of mediocre engineers, but if you can go to a good school and put in your time to advantage, and come

out and make something of yourself, all right; otherwise, do as your father would like and go into the store." I selected my school and went. Fortunately, soon after I arrived a personal friend on the Faculty impressed upon me the fact that I was there for a Bachelor degree. He said, "you will not be a Mechanical Engineer after you graduate in four years' time, and probably you will not know just what line you will follow. Instruction is graded and laid out to suit, as nearly as we may, the needs of the great number of students we have to handle, and they are all put through practically the same curriculum."

I believe that the four years in the undergraduate work cannot be made thoroughly practical. The thought of striving to make practical men by technical training, I cannot regard as quite right. I do not mean that a man, when he gets out of school, should not know what he wants to do, but I believe that the specialization should come, as Prof. Freeman has mentioned, at the suggestion of the Instructors, as they are in position to observe a man's ability and tendencies. It was never done for me, but I should prefer to regard the four years' work as entirely an investment of time and expense in absorbing the ground work. Then a man could specialize, in Post-graduate work, or could start immediately on some practical work to continue his learning. In other words, after four years of fundamental study, without income, he can start in on his practical learning at a moderate salary, which will give him his living; then some day he may hope to be an engineer and make money.

The technical instructor (and when I say this I do not mean any discourtesy to instructors), must necessarily be a teacher of history—of what has been, not less than of what is doing today. The greatest advances and developments in a practical way are made by the producers rather than by the college professors, although the research work done in the college forms a basis for the advances made by the active engineer. If then the instruction can lead a man to graduation well up-to-date with what is going on he ought to be capable of going into active work, taking things as he finds them, and continuing with the procession.

I can look back just ten years to my leaving college, and I recognize a great many things in my subsequent experience wherein I have failed to keep up with what I would like to have been, but I have never been inclined to blame my technical instruction for that. I have always regarded it as a failure on my own part to get the best there was for me. There were many things there for me that I did not get.

*Mr. Howlett:* Prof. Freeman has suggested that if an engineer happened to possess all the qualities embodied in J. G. White's specifications, he would make a successful Insurance President, and not need to work for $10,000 a year. This brings to my mind the story of two Iowa farmers, who wrote to a manufacturing concern for a price on some saw-mill machinery; they stated that they had

$600.00 between them, and asked how large a saw-mill they could buy for that price. The manufacturers replied that the smallest saw-mill they had cost $10,000. The farmers then answered, "What would we want of a saw-mill if we had $10,000?"

*Mr. Raymond:* I spent five years at a famous eastern college; there were many things which were not as I would like to have had them, and many things in which I would recommend a change; it would take me at least four years to enumerate them.

As I look back over my college days I recall that the line of *sales engineering* was one thing not taught in the college rooms or the laboratory. Also, Mr. DeWolfe has spoken in favor of the study of history, political economy, etc., and in this I agree with him heartily.

One thought I would like to impress upon you, along the lines of what is commonly known as "mixing"; that is, making friends, knowing your fellow man, and not only knowing him but loving him, and I might say, getting his love. I would also like to emphasize the fact to students of taking advantage of whatever is offered in the school rooms, in the lecture rooms, in the class rooms, shops, etc., thus getting a broader view of life.

*Mr. Hatch:* It occurs to me that there are a good many things taught in the colleges that we cannot apply, just as we get them, to any problem that comes up. I find, too, that some of the best engineers I know, never studied engineering in college, but are college men. At the time they were in college, the engineering that they are now practicing had not been thought of. This is true in my own case. The engineering I am practicing now had not been dreamed of at the university where I received my training, in my college days.

My experience leads me to believe that the mental training we get in the University is the thing that is going to be of benefit to us, and I think that every college professor should, if he feels real kindly toward his students, tell them very plainly (perhaps not until they have reached their senior years) that probably many of the things they have been taught may never be put into practical use; but that me things they have studied and earned will serve to assist them in solving similar problems which they will meet, but will not give them the exact formula by which each problem may be solved.

For it is quite possible that in a few years they will be taking up problems that they had not dreamed of at the time they left college.

Perhaps my experience has been different from others, but I am a strong advocate of a college training, with as little actual shop work, and work of that nature, as can be used properly to illustrate what is being taught from the books. It seems to me that the principal thing we get is simply the training.

*Closure.*

*Prof. Woodworth:* In closing I want to make special mention of the point made by Mr. Hatch. Mr. Hatch has become a successful engineer, and has referred to a matter of ancient history. Technical school men should be so trained that they can adapt themselves to changes in the art. We want adverse criticisms that will help us to correct the mistakes.

The older graduates sometimes express themselves in this way: "In our college course we were fooled on nomenclature. We were told that in our senior year we would have a course in advanced dynamo engineering work for practice. We were gradually led up to that by being told the first year that the second year we could look into the room where there was a dynamo, then that the third year we would walk into the room where the dynamo was, and that the fourth year we could go into the dynamo room for laboratory work. But what really took place was that we went in and watched the professor operate the machine."

Recent graduates say, "We were told that we were going to have a course in advanced dynamo engineering. We went into the dynamo room and were put under the direction of a bright young man who gave us the course, but we have since found out that the young man who gave the course had never had a day's experience in his life. This is one of the failings of the technical schools of today. The only difference between such technical work and actual work in the factory is that the man in the factory has actually had experience. At the time I finished the technical school there had just come to the school an alternating current machine. We went into the laboratory and saw it unpacked. We had never in the whole course, discussed alternating currents. It is only within the last few years that we have been told about high tension electrical transmission. In these days there are constant changes in electrical apparatus as well as in other things. The difference between the college man and the fellow who has only practical training is that the man of merely practical training is limited when it comes to a change; the college man should not be limited when it comes to a change. There are splendid practical men who have really had to drop engineering work in order to give place to technical men, because of recent changes in the art.

Prof. Freeman gave you a definition of "education." Definitions of education are in a rapid stage of transition. I believe it was in the year 1500 that we first had the word "education." Prof. Sheldon has said, "Education is the development of the power of expression—in language or action." You will notice that this definition covers both schools. We are supposed to belong to the school of action, always remembering that clear expression of either kind must always be preceded by clear thinking.

In regard to the question of a general technical education as brought out by Mr. Hatch and others, I have made a few notes from papers by four of the leading men of this country,—Stein-

metz, Raymond, Buck, and White, and made a classification of what they considered the things which should constitute good, broad, general, technical education. Mr. Raymond stated that more stress should be laid on mathematics, physics, chemistry, thermodynamics and laws of electricity. Mr. Buck,—Be thorough and have a special training in mathematics, physics, mechanics, chemistry, electricity. Mr. Steinmetz,—The idal course consists in mathematics, physics, chemistry, mechanics, and laboratory work at the beginning, in the middle and at the end. Mr. White,—mathematics, physics, mechanics, chemistry, and fundamental engineering principles.

It looks as though these authorities had gotten together. Practically every speaker this evening followed the same line.

The question of specialization was dealt with very rigidly by Mr. Steinmetz in his article. On this subject he says:

> "One of the reasons of the inefficiency of the present college "course is the competition between colleges. By each college "trying to teach more than any other the quantity of material "taught has gradually increased so that it is no longer possible "to give a thorough understanding and memorizing takes the "place of understanding. Memorizing however is an entirely "useless waste of energy since anything that is not perfectly "understood, but merely memorized, will be forgotten in a short "time if not continuously applied, and if continuously applied it "would be remembered anyway. If of the amount of material "in electrical engineering as well as other branches which the "educational institution of to-day attempt to teach, one-half or "more should be dropped altogether, and the rest taught so as "to be fully understood, with special reference to general prini- "ples and methods, the product of the institution would be far "superior and more successful in practical life."

They are to give the student all the ground work required to be successful in future practice, but not the impossible aid of giving him a complete education as a practical engineer.

Hardly a day passes that we do not receive at the Lewis Institute a telephone message asking for a man for some special line of work. It rarely happens that we go to our collegiate day-school students and say, "Here is some one who wants a special man; you are he." But we go to our list of several hundred students taking special courses in the evening. These men are special men; men who fit only special jobs. The regular student who has taken a general technical training should be ready for anything.

The question of the relation between telephone engineers and the technical school was brought up by Prof. Carhart. The question of the Mechanical, Civil, and Electrical engineers should all be resolved into one thing—the engineer. The Stevens Institute established this idea first, when they said they would incorporate practically all those things into one thing, and then found the fundamental thing from which all those others branched, and then called that one thing "mechanical engineering."

# ABSTRACT OF THE MINUTES OF THE SOCIETY.

Minutes of Regular Meeting, April 4, 1906.

A regular meeting of the Society (No. 572) was held Wednesday evening, April 4th. It was called to order at 8:15 p. m. with Past President Carter in the chair, and about 60 members and guests present.

The secretary read the minutes of the meetings held March 7th and 21st, which were approved.

The secretary reported from the Board of Directors the election into the Society, at a recent meeting, of the following:

| | GRADE |
|---|---|
| George H. Herrold, Red Wing, Minn | Active |
| George F. Maddock, Chicago | Active |
| Horace J. Pettee, Chicago | Junior |
| Louis J. Hotchkiss, Chicago | Active |
| Albert A. Aegerter, St. Louis, Mo | Active |
| Merton G. Hall, Centerville, Iowa | Active |
| Thomas F. Geraghty, Chicago | Junior |
| Andrew J. Hemstreet, Texico, N. M | Active |
| James Lyman, Chicago | Active |

Also that the following had made application for membership:

Robert M. Black, Chicago.
James Barr, Chicago.
John G. Archer, Chicago.
Charles W. Morey, Chicago.
Henry R. Wahl, Chicago.
Albert M. Currier, E. Carondelet, Ill.
O. P. Chamberlain, Chicago.
Warren A. Hoyt, Chicago.
Olin H. Basquin, Evanston, Ill.

The secretary also reported that Mr. Bainbridge had tendered his resignation from the office of trustee, to which he was elected in January, 1906, because of absence from the city, and that this resignation had been accepted by the Board of Direction, who had also elected Mr John Brunner to fill the vacancy for the unexpired term; also that Mr. Brunner would be chairman of the Library Committee for the remainder of the current year.

There being no other business to bring before the Society, Mr. A. W. Merrick, M. W. S. E., was introduced, who presented his paper, (which had been printed and sent out in advance) "The Clay Slide at the Boone Viaduct, Boone, Iowa."

Written discussion was read by the secretary from Dr. U. S. Grant and Mr. C. F. Loweth. Discussion followed from Messrs. Tratman, L. K. Sherman, E. C. Carter and Zinn.

The meeting adjourned about 9:15 p. m., after which some light refreshments were served, provided by the Entertainment Committee.

Minutes of Extra Meeting, April 18, 1906.

An extra meeting of the Society (No. 573) was held Wednesday evening, April 18th. The meeting was called to order at about 8:20 p. m., with Vice President Andrews Allen in the chair and about 55 members and guests present. There was no business to bring before the Society, so the chairman introduced Mr. Eldridge, who, on behalf of and in the absence of Mr. Cartlidge, read the paper written by him on "The Design of Swing Bridges, from a Maintenance Standpoint." This paper had been printed and sent out in advance. Discussion of the paper was offered by Messrs. Allen, Finley, Eldridge, Loweth, Reichmann, and B. B. Carter. There were lantern slide illustrations for the original papers and for Mr. Allen's discussion.

A resolution was offered by Mr. Finley, and duly passed, that further discussion of this subject be held on the evening of May 16th.

The meeting adjourned at 10:05 p. m.

Minutes of the Regular Meeting, May 2, 1906

A regular meeting of the Society (No. 575) was held Wednesday, May 2, 1906. The meeting was called to order at 8:15 p. m. with Vice President Abbott in the chair and about 30 members and guests present. The Secretary read the minutes of the meetings of April 4th and 18th, which were approved. The secretary reported from the Board of Direction, the election into the Society of the following:

Hugh A. Johnson, Maywood, Ill....................Junior
Robert M. Black, Chicago....................Junior
James Barr, Chicago....................Active
John G. Archer, Chicago....................Associate
Chas. Wm. Morey, Chicago....................Active
Henry R. Wahl, Chicago....................Active
A. M. Currier, E. Carondelet, Ill....................Junior
Oscar P. Chamberlain, Chicago....................Active
Warren A. Hoyt, Chicago....................Active
Olin H. Basquin, Evanston, Ill....................Active
Oscar E. Strehlow, Chicago....................Active

Also that applications for membership had been received from the following:

H. Foster Bain, Urbana, Ill.
Chas. M. Wood, Palestine, Texas.
Allan H. Stone, Pawnee, Ill.
Wm. E. Millar, Charleston, Ill.

Announcement of the death of our Past President H. W. Parkhurst, Saturday evening, April 7th, was made, and that a meeting of the Board of Direction was convened Monday morning, April 9th, with other members of the Society also present, when the following were appointed as pall-bearers, to attend the funeral services held that afternoon at 3 o'clock at Christ Church, 24th St. and Michigan Ave.: Messrs. Octave Chanute, H. E. Horton, Robert W. Hunt, Onward Bates, W. L. Abbott, Andrews Allen, R. Modjeski, F. H. Bainbridge, W. E. Angier, C. F. Loweth, A. S. Baldwin, G. H. Scribner, Jr., David Sloan, H. R. Safford, R. E. Gaut and J. H. Warder.

As is the usual procedure, a motion was made that the chair appoint a committee of three, to prepare a memorial of Mr. Parkhurst to be published in the Journal and a copy to be sent to the family of Mr. Parkhurst. The motion being carried, the chair (Mr. W. L. Abbott) appointed as members of that committee Messrs, E. L. Corthell, Chairman; A. S. Baldwin and H. H. Hadsall.

The secretary stated that an invitation has been received to attend the launching of a large steel ore freighter, the J. Pierpont Morgan, at the yards of the American Ship Building Co. at South Chicago at noon Saturday, April 21st, but that the invitation was not received in time to get out notices to the members of the Society. Word was sent out, however, by telephone to such as could be reached. A special train was provided by Mr. Banks of the E. J. & E. R. R., which left the La Salle St. station at 10:45 a. m. and brought the visitors back to the city about 1:15 p. m. This steel cargo steamship is one of the largest on the Great Lakes, being 600 feet long over all, 58 feet beam and 32 feet deep, with a cargo capacity of 15,000 net tons of iron ore. The vessel will run between Lake Superior and South Chicago or Lake Erie ports. The launch was very successful. A sister ship of the same dimensions, the H. H. Rogers, was under construction on the opposite side of the slip and is to be launched in the near future.

There being no other business before the Society, the chairman introduced Mr. J. W. Alvord, who read the paper, "Development in Mechanical

Filtration," written by Mr. R. E. Milligan, as the author could not be present. There were a number of lantern slides illustrations sent with the paper by Mr. Milligan. Discussion followed from Messrs. Mead, Denison, W. L. Abbott, Walter Wagner and Alvord as a closure.

The meeting adjourned at 10:15 p. m.

Minutes of the Extra Meeting, May 16, 1906.

An extra meeting of the Society (No. 576) was held in the Society rooms, Wednesday evening, May 16th. The meeting was called to order at 8:30 p. m., with Vice President Andrews Allen in the chair, and about 65 members and guests present.

There was no business to bring before the meeting, so the chairman announced that the first paper for the evening was on "Fireproofing of Steel Buildings," by Gen. William Sooy Smith. As Gen. Smith was in California the paper was read by the secretary.

The next paper was presented by Mr. W. H. Finley on "The Design and Maintenance of Machinery for Swing Bridges," which was virtually a continuation of the discussion of the paper by Mr. Cartlidge, presented April 18th, "Notes on the Design of Swing Bridges from a Maintenance Standpoint."

Discussion was presented in writing from Messrs. Bainbridge, Eldridge and C. C. Schneider, which was read by the secretary, Mr. Belknap also presented written discussion. Other discussion was offered by Messrs. Schaub, Vent, Allen and A. F. Robinson.

Lantern slide illustrations were employed.

The meeting adjourned about 10:40 p. m.

## ELECTRICAL SECTION.

Minutes of the Meeting, April 20, 1906.

An extra meeting of the Society (No. 574), being the Sixteenth meeting of the Electrical Section, was held in the Society rooms Friday evening, April 20th.

The meeting was called to order at about 8:20 p. m., with Mr. P. Junkersfeld, vice chairman of the section, in the chair and about 40 members and guests present.

There was no business before the section, so Mr. Albert Scheible was introduced, who read his paper on "What Degree of Accuracy is Feasible and Necessary in Wiring Calculations."

Discussion followed from Messrs. Junkersfeld, Damon, Morgan Brooks, Scheible and Woodworth.

The meeting adjourned about 10:00 p. m.

Minutes of the Meeting, May 18, 1906.

An extra meeting of the Society (No. 577), being the Seventeenth meeting of the Electrical Section, was held in the Society rooms Friday evening, May 18th.

The meeting was called to order at 8:20 p. m., with Mr. McMeen, chairman of the Electrical Section, in the chair and about 55 members and guests present.

The minutes of the sixteenth meeting, held April 20th, were read and approved.

There being no other business before the section, Mr. H. R. King was introduced, who read his paper descriptive of The Hawthorne Shops of the Western Electric Company. This was illustrated by a large number of lantern slides.

Discussion followed from Messrs. McMeen, Scheible, Warder, Miller, Spurling, F. M. Davis, Hitchcock, and King.

The meeting adjourned about 10 p. m.

J. H. WARDER,
*Secretary.*

## BOOK REVIEWS.

Fowler's Mechanical Engineers' Pocket Book for 1906, Wm. H. Fowler, M. Inst. C. E. etc., Scientific Publishing Co., Manchester, Eng. 4 by 6 ins. 516 Pages—Leatherette—Red Edges—Tables, Diagrams, etc., Price 1 Shilling 6 pence.

This is a small reference hand book rather than a pocket book, as the title would indicate, and contains about five hundred pages of information usually found in such books. The first one hundred pages are devoted to the usual tables of weights and measures, logarithms and trigonometrical functions, followed by tables of weights of sheet metal, etc. The next two hundred pages are devoted to steam and steam machinery and gas engines, and the greater part of the remainder of the book is devoted to information useful to metal workers.

That portion of the book which impressed the reviewer the most favorably is the twenty-five pages devoted to the discussion of Entropy. The author treats this subject in such a matter-of-fact way, using such simple and homely illustrations that the lay reader does not become bewildered, as he so often does, when confronted at the beginning of the discussion by Greek letters, deferential symbols and the statement that he is dealing with a "ghostly quantity."

After reading in the author's Preface that this fresh edition "is made the opportunity for correcting typographical errors and making such revisions as are necessary to bring it up to date," the reviewer confesses to some disappointment at finding only two pages devoted to the steam turbine, and only six pages, including a half page advertisement of Fowler's Electrical Engineers' Year Book, devoted to the subject of electricity.

The book which is advertised at the very moderate prices of thirty-six and fifty-four cents respectively for the two different kinds of binding, naturally lacks both the volume of information and the mechanical construction and finish of higher priced hand-books, and it is doubtful if it would hold together long if used as a "pocket-book," but for information relating to steam machinery and machine shop work, it will be found a convenient and ready reference. W. L. A.

The Indicator Handbook,—A Practical Manual for Engineers, by Charles N. Pickworth, Ed. of The Mechanical World, Manchester, England.

Part I, The Indicator; its Construction and Application. Manchester, Eng., Emmott & Co., Limited, 65 King St. 5 by 7½ ins. 130 pp., including index, 81 illustrations. Cloth; price 3 shillings, net.

The "aim" of this little book is to furnish engineers with a practical handbook of the modern Indicator, examining in some detail the errors of the instrument.

Examination of the book "indicates" that this and more has been accomplished. The descriptive portion begins with the immortal Watt's simple instrument, and after describing the common English and American forms, concludes with the external spring and continuous indicators of the latest forms. A word in passing is also given to effective and to mean pressure indicators, as well as to special forms.

The chapters on the "errors of the indicator," "errors of indicator connections," "errors of indicator reducing gear," each following the corresponding descriptive matter, are well worth careful attention. The thoughtfulness of the author is shown, for instance, by his statement of the amount of stretch per foot in length, of iron wire used in making wiring connections per pound of tension. The layman is apt to think, or rather not to think,

of any such possibility. The book concludes with a chapter on the "use and care of the indicator," not forgetting to call attention to the need for carefully cleaning the instrument after use, and to urge intelligent handling of these excellent pieces of design and workmanship.

C. V. K.

THE ADJUSTMENTS OF THE ENGINEER'S TRANSIT AND LEVEL. By Howard C. Ives, C. E., Assistant Professor of Civil Engineering, University of Pennsylvania. John Wiley & Sons, New York, 1906. 4¼x6¾ inches; 15 pages; boards. Price 25c.

The principles upon which the adjustments of the engineer's transit and level are based, also the practical methods of applying those principles in the actual adjustments of the instruments, are very clearly and concisely explained in this little book. In the introduction the author points out that all adjustments are founded upon common sense principles, and that, with a clear understanding of these, a student need not depend upon his memory alone, in deciding on the order of the adjustments, or the methods of making them.

The pages devoted to adjustments are divided about equally between the level and transit. The sketches are clear, and in them and in the text the author has taken care to present the fundamental principles with the methods of making the adjustments.

The book will be found to be a useful one for those desiring a separate explanation of the subject.

M. B. W.

THE MANUFACTURE OF CONCRETE BLOCKS, AND THEIR USE IN BUILDING CONSTRUCTION, by H. H. Rice, Denver, Wm. M. Torrance, Yonkers, N. Y., and others. The Engineering News Publishing Co., New York, 1906. Cloth, 5¼x9 ins. 122 pages, including copious index. Very fully illustrated. Price $1.50 net.

This book is made up of a series of articles on concrete blocks by different authors, being those submitted in competition for money prizes of $250 and $100 offered jointly by "Engineering News" and "Cement Age" of New York City. The articles appeared originally in these periodicals.

The first prize paper is by Mr. H. H. Rice, Sec'y of the American Hydraulic Stone Co. of Denver, Colo. Mr. Rice discusses the composition and proportions for concrete, the manufacture, curing, facing and cost of concrete blocks, and method of wall construction. The three processes of manufacture, tamping, pressing and pouring are described together with the types of machines for making the five different classes of blocks for hollow walls.

The second prize paper, by Mr. Wm. M. Torrence, M. W. S. E. also discusses the proper ingredients and proportions for concrete. Regarding waterproofing of blocks, Mr. Torrence says: "No waterproofing scheme will strengthen the concrete and many methods for waterproofing damage the cement." Mr. Torrence takes up the important question of the numerous concrete block patents. In 1904 alone about sixty patents on building blocks were granted. Many of these patents evidently conflict. Comparison is made of the cost of buildings of concrete blocks and other materials. It is gratifying to note that neither of the writers make exceedingly low estimates of cost of concrete block work. The advertising literature of block machine makers is very misleading in this respect. Mr. Torrence's paper is well illustrated.

Besides the two prize papers, abstracts have been made from nine other papers submitted. These abstracts are statements of the experience or views of the different writers covering new points, or further exemplifying points on concrete block manufacture.

This book, which is the only one published on the subject, is a valuable contribution to the rapid evolution of an industry which is attracting great

attention. The book is by no means a treatise. It is a compilation of experiences of concrete block makers. Little attempt has been made to summarize or criticise the view of the different writers. Considering the fact that most of the writers are interested in some particular patented process, there is gratifying absence of any attempt to advertise any particular block.

The main cause of lack of greater progress in the concrete block industry comes from the apathy of the architect. In this connection we criticise the statement of Mr. Rice. "There is no apparent reason why the size of concrete blocks should not be as standard as the size of bricks." Art will not stoop to the concrete block maker. Different structures require different architectural treatment. The success of the block maker depends on his ability to comply with architectural requirements. It is for the architect to specify what these requirements are. So far he has neglected to do this. A chapter by an architect on this feature of the concrete block industry would be a valuable addition to the book. We commend the excellent introduction of the book to the careful attention of every architect and block maker. L. K. S.

Smoley's Tables,—Parallel Tables of Logarithms and Squares, Angles and Logarithmic Functions, etc., for Engineers and Architects. By Constantine Smoley, C. E. New York, 1906, third edition, Engineering News Publishing Co. Flexible Leather, 5 by 7 ins. 331 pages. Price $3.00 net.

The first of these tables are in two sets, according to the magnitude of the subdivisions. The first set, which was published in the earlier editions, takes all lengths up to 50 feet, with subdivisions by inches and to thirty-seconds of an inch. For each length varying by thirty-seconds of an inch, from one-thirty-second of an inch up to 50 ft., the table shows in parallel columns the value of the square and the logarithm. In the second set of tables the variation between successive lengths varies by sixteenths of an inch, and is extended from 50 ft. to 100 ft. This wide range of lengths, with corresponding value of the logarithm and of the square, makes this little book a valuable adjunct to the desk and draughting board of engineers and architects.

In the draughting room of bridge shops, and with architects, a bevel of a piece of framing is commonly given as the rise (in inches and fractions) to a given base, taken at 12 ins. Another table in this book is the angular value, and the logarithmic trigonometrical functions of the same for a range of bevels, from one-thirty-second of an inch up to 12 ins., varying by thirty-seconds of an inch, referred to a standard base of 1 ft.

To make the book yet more complete, the author has introduced a logarithmic table of five figures for numbers up to 1000. Finally, there is a table of decimal equivalents to the subdivisions of 1 ft. by inches, and thirty-seconds of an inch. Some few pages of explanations, with diagrams, and some examples worked out show the comprehensiveness of the book. Of course such a book as this is valuable as a working tool, and in this connection it is pleasant to note the good, serviceable quality of the paper and binding, and the excellence of the typographical press work.

W.

Gold Dredging,—Annual Supplement for 1906, by Capt. C. C. Longridge, M. Inst. M. E. "The Mining Journal," London, 6 by 10 ins., cloth, 67 pages. Illustrated by half-tone cuts, and folding plates. This is a Supplement to the original work which was reviewed in the Journal February, 1906.

The work is a combination of text book and engineer's pocket book, and is filled with valuable information and suggestions.

The present Supplement is more devoted to American practice than the original work. The chapter on suction-producer-gas engines is particularly

interesting and instructive. The table of bucket capacity, horse power consumed, monthly output, and height of lift, is new, and valuable to intending dredgers.

The chapters of the Supplement, refer by number and page to the corresponding chapters of the original work, and the Supplement contains new chapters on "The Submerged Jet Dredge," and on "Gas Engines and Light Motors."

In addition to the "Table of Contents" at the beginning, an "Index" at the end facilitates consultation of the work. The typographical work is excellent.

W. S. B.

Shaft Governors, by W. Trinks and C. Housum,—97 pages, 3½ by 6 ins., many illustrations, including 6 folding plates and 16 tables. Van Nostrand Science Series, No. 122. Boards. Price 50 cents.

This treatise on the mathematics of shaft governors would have been very valuable a dozen to twenty years ago, when there was a great development of high-speed, automatic engines for electric generation, and when engine builders generally relied upon the cut and try method, and almost every shop had evolved by trial and from experience its own design. But this period of experimentation has resulted in reducing the subject of shaft governors to such simple and reliable designs, it would not seem that there would be such a demand for this book at this date. Nevertheless, the work with its diagramatic and mathematical solution of the resultants of the various forces in action is a valuable study, and is worth much to the younger engineering students and draughtsmen engaged in engineer design, to more perfectly educate them in this part of their work.

A careful study of the book, applying the analytical solutions to the work that is under construction and operation under their own eyes, would be of great value to them. Yet it must be remembered that there are many forces in operation in the action of the governor that cannot be accurately determined in advance, and that in the future as heretofore the most satisfactory and reliable shaft governors will be obtained by modification of the several elements, by careful experimentation, and noting results after working out a design based upon such information as may be obtained from such a text book as this. And this book is notable, in that it does contain this information, properly arranged and presented for such study, and which has not been put in type before, as far as the observations of the reviewer go.

S.

Notes on Electro-Chemistry, by F. G. Wiechmann Ph. D.—McGraw Publishing Co., New York, 1906. 6 by 8¼ ins., 145 pages, including index. Cloth bound. Price $2.00 net.

This book, in the language of the Author, is intended to "meet the needs of students entering upon the study of electro-chemistry and of chemists interested in the application of electrical energy to chemical problems." It is a book of 137 pages, and in the introduction chapter is briefly discussed the general principles of science, including terms and general theories relating to matter and energy and the units used in physical measurement.

Chapter 2 begins with a historical treatment of the theories of electricity and includes several pages on radio-activity. The properties of electricity and the laws, terms and values are also treated in this chapter.

Chapter 3 devotes about six pages to the evolution of electrochemistry; electrolysis with the constants and terms used follow. Electro-motive force and several pages on the dissociation voltage conclude the chapter.

Chapter 4 is largely devoted to the ion theory, which are discussed fully and consistently. Conductivity naturally follows and the chapter is concluded with a short account of migration of ions.

Chapter 5 treats of electro-analysis. This chapter is not designed to

give methods for electro-analytical work but deals with theoretical considerations and is suggestive only.

Chapter 6, 40 odd pages, treats of electro-technology and is an outline only and deals with the principles and theories involved without going into details as to the methods used.

At the head of each chapter in the book there is quite a complete bibliography of the matters treated of. The subject index might have been made fuller and more in detail to advantage. The book is well adapted for the purpose and will save much time for the chemical student who desires to know something about electrochemistry in particular, and also for the technologist who wishes to have a concise treatise dealing with the principles involved in electrochemical work. W. H.

THE BUSINESS OF CONTRACTING, by Ernest McCullough, M. W. S. E. Reprinted from "The Contractor," Chicago, January, 1906. Technical Book Agency. Pamphlet, 5¼ by 7½ ins. 45 pages. Price 50c. postpaid.

This little book is made up of seven chapters which treat on the several phases of the subject.

Chapter I treats of "The Staff" of the organization, consisting of the President and Directors of the Company, the Manager, Superintendent, etc.

Chapter II describes "The Foreman," and contains a good deal of valuable advice and instruction.

Chapter III, "Bidding on Work," contains some interesting statements relative to this subject, and the author advances the proposition that less money is lost by Contractors taking the work at low figures, than by poor management after the contract has been awarded and work is begun on the job. Too much stress cannot be laid on the necessity of the Contractor giving most careful attention to all the items and clauses of the specifications. Sometimes an apparently innocent and almost unnoticed clause, if overlooked by the Contractor, will be the cause of much subsequent trouble, and even loss. These contradictory clauses might not be sustained in a trial before a reputable judge, but here, as often elsewhere in other business transactions, it is frequently better to put up with some loss than to go to law about it, with the expense and annoyance thus entailed.

Chapter IV gives "Hints on Bidding," which is full of interest, even to those who are not Contractors. It contains many excellent suggestions for the accumulation of valuable Cost Data, based on actual work done. There are some tables which will greatly assist in making estimates as for hauling, cost of material, of labor, etc.

Chapter V, on "Working Methods," and Chapter VI, on "The Office On The Work," are also full of valuable suggestions relating to management, keeping a close account of the cost of work done, by means of which the cost of work may be reduced, and the efficiency of the whole organization increased.

The final Chapter VII relates to "Field and Office Methods," when further hints are given for systematizing the work, keeeping track of what is going on, and on page 44 is a summary of the essentials to successful contracting that it would be well to "print large" and hang up in the office of the Contractor.

Altogether the little pamphlet will be found "mighty interestin' readin'," as Mr. Greeley used to say, and should be of great value to those about to embark in this line of business. W.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for April, 1906, we have the pleasure to report the following additions to the library and gifts from donors named:

### MISCELLANEOUS GIFTS.

Pratt Institute, Brooklyn, N. Y. Annual Report of the Secretary and Treasurer, 1904-5. Pamphlet.

Ohio State Board of Health, Springfield, Ohio, 19th annual report. Cloth bound.

Tratman, E. E. R., Chicago,—as follows:

- Proc., Master Car Builders' Association, Vol. 38, 1904. Cloth.
- Proc., Railway Signal Association, 7 pamphlets.
- Proc., New York Railroad Club, 5 pamphlets.
- "Building Ordinances," City of Chicago, March, 1905. Cloth.
- "Statistics of Railways in the United States—Interstate Commerce Commission. 1904." Cloth.
- "The Copper Handbook," by H. J. Stevens. Vol. V, 1904. Cloth.
- "Who's Who in America," Mechanics' Association, Vol. 37, 1904. Cloth.
- "Hydraulic Agricole et Urbaine," by G. Bechmann, 1905. Pamphlets.
- "Proc. Amer. Ry. Master Mechanics' Asso'n, Vol. 37, 1904. Cloth.
- "Question VIII, Electric Traction, International Ry. Congress, Washington, 1905." 4 pamphlets.
- "Bridge and Tunnel Centres, by McMaster, 1893" Cloth.
- "Handbook issued by Cambria Iron Co. on Cambria Steel, 1898." Leather.
- "Rules and instructions for the government of employees of the Maintenance of Way Dept. adopted by the Houston & Texas Central R. R. Leather bound.
- "A New System of Heavy Goods Transport on Common Roads, by Diplock." 1902. Cloth.
- "U. S. Dept. of Agriculture, Office of Experiment Station, Report of Irrigation Investigations for 1900, Nos. 1, 2, 3 and 4." 4 pamphlets.
- "U. S. Dept. of Agriculture, "Irrigation on the Great Plains by Newell." 1896. Pam.
- "U. S. Dept. of Agriculture,—Construction of Good Country Roads, by Eldridge." 1898. Pam.
- "U. S. Dept. of Agriculture,—Steel-Track Wagon Roads," by Dodge. 1898. Pam.
- "U. S. Dept. of Agriculture,—Earth Roads, their construction and repair," by Stone. 1894. Pam.

Wallace, John F., M. W. S. E., Chicago.

- "Some Phases of the Panama Problem." March, 1906. 2 Pam.
- "Statement, The Panama Canal and the Panama R. R." Mar. 20, 1906. Pam.
- Supplemental Statement of Mr. John F. Wallace, Panama Canal, May, 1906. Pam.
- "Testimony, Isthmian Canal." Cloth bound.

University of Illinois, Urbana, Ill., Register for 1905-6. Pam.

University of Montana, Missoula, Mont., "The Butterflies of Montana, Bulletin No. 30." Pamphlet.
Rose Polytechnic Institute, Terre Haute, Ind. "24th annual catalogue, 1906." Pamphlet.
University of Illinois, Urbana, Ill., The Technograph, No. 18. 1903-4. Pam.
University of Michigan, Ann Arbor, Mich., Calendar for 1905-6. Pam.
Frank G. Ewald, M. W. S. E., Springfield, Ill., Report of R. R. & W. Com. of Illinois for 1905. Leather.
Board of Health, Manchester, N. H., "Statement of Mortality for March and April, 1906." 2 pams.
Michigan Agricultural College, Experiment Station, Bulletins 235, 236 and 237, Feb., April and May. 3 Pams.
Mass. Board of Railroad Commissioners, 37th annual report of Railroad Commissioners of Mass., 1906. Returns of 1905. Cloth.
John Wiley & Sons, New York, "The Adjustments of the Engineer's Transit and Level." Howard C. Ives.
Engineering News Publishing Co., New York, "The Manufacture of Concrete Blocks and their Use in Building Construction," by Rice and Torrance.
Engineering News Manual of Examinations for Engineering Positions in the service of the City of New York. Vol. 1, Part 1."
Emmott & Co., Ltd., Manchester, Eng., "The Indicator Handbook," by C. N. Pickworth. Cloth.
McGraw Publishing Co., New York N. Y. "Details of Bridge Construction,—Plate Girders." Skinner. Cloth.
Scientific Publishing Co., Manchester, Eng. "Practical Testing of Dynamos and Motors," by C. F. Smith.
New Jersey State Board of Health, "29th annual report, 1905." Cloth.
Warder, J. H., Sec'y, W. S. E., Chicago,
The Combustion of Coal, by Wm. Barr, 1879. Cloth.
International Scientific Series,—10 vols. Cloth.
Van Nostrand Science Series,—8 vols. Bds.
U. S. Commissioners, Reports Vienna International Exhibition, 1876, 4 vols. Cloth.
"Engineers' and Surveyors' Instruments." Buff and Berger. Bds. 1897.
From R. B. Warder Estate, the following:
8 vols., paper, and 15 vols., cloth, Proc. Amer. Assoc. for Advancement of Science.
Modern Organic Chemistry, by C. G. Wheeler. Cloth.
Principles of Geology, by Lyell. Cloth.
McGraw Publishing Co., New York, N. Y.
Notes on Electrochemistry, by Wiechmann, 1906. Cloth.
High-Tension Power Transmission,—2nd volume, by McGraw Pub. Co. 1906. Cloth.
Electric Transmission of Water Power, by Adams. 1906. Cloth.
John Crerar Library, Chicago, Eleventh Annual Report, 1905. Pam.
John Brunner, M. W. S. E., Chicago,
P. W. Almquist, on Bridge Construction. Cloth.
The Forth Bridge, reprinted from "Engineering," Feb. 28, 1890. Cloth.
Record of Arch Development, from "Oesterr. Ingenieur und Architekten-Verein." 1895. Cloth.
The National Geographic Magazine, 13 Numbers 1905-6. Paper.
State of Rhode Island and Providence Plantations, "Annual Report, Commissioner of Dams and Reservoirs, Jan. 1906." Pam.
J. Robert Crouse, "Profitable Co-operation." Pamphlet.
State of Ohio, Highway Department, Columbus, Ohio, Bulletin No. 7, May, 1906. Pam.

South Park Commissioners, Chicago, Annual report for fiscal year, 1905 Pam.
W. S. Bates, M. W. S. E., Chicago,
"Der Vogelflug als Grundlage der Fliegelkunst," by Lilienthal. Cloth.
American Society of Refrigerating Engineers. New York. Constitution, and By-Laws, Officers and Members.

## EXCHANGES

Iowa Engineering Society, Proc. 18th annual meeting, 1906. Pamphlet.
American Electrochemical Society, Philadelphia, Pa., Transactions, Vol. VIII, 1905. Cloth.
Lake Superior Mining Institute, A. J. Youngbluth, Sec'y, Vol. XI, Proc. of 11th annual meeting, 1905. Pam.
Association of Ry. Supts. of Bridges and Buildings, Proc. 15th annual convention, 1905. Pam.
National Fire Protection Association, New York, pamphlets,
"Standard for Fire Hose and Hydrant Couplings."
"Proc. of Ninth Annual Meeting, 1905."
"Articles of Association, Officers and Committees, Membership, 1905-6."
"Bulletin to Members."
"Quarterly Bulletin of the Committee on Special Hazards and Fire Record, Jan. 1904."
Illinois Society of Engrs. & Surveyors, 21st annual report, 1906 Pam.

## GOVERNMENT.

U. S. Navy Dept., Bureau of Steam Engineering, Annual Report of the Chief of the Bureau. Pamphlet.
U. S. Geological Survey, Department of Interior,
Production of anthracite coal in 1905. Pamphlet.
Water Supply and Irrigation Papers 154 and 167. Pamphlet.
Bulletin No. 269, Economic Geology. Pamphlet.
Professional Papers, Nos. 44 and 48—parts 1, 2, and 3. Pamphlets.
Interstate Commerce Commission, Washington, D. C., Nineteenth Annual Report. Cloth.
Dept. of Commerce and Labor, Bureau of the Census, Bulletins No. 35, 36, 37, 38 and 40. Pamphlets.
Supplementary Analysis and Derivative Tables, 1900. Cloth.
U. S. Government, Washington, D. C., Price List of U. S. Public Documents No. 9. Pam.
U. S. Geological Survey, Depart. of Interior, Reclamation Service, Specifications Nos. 86-96 inclusive. Pamphlets.
Isthmian Canal Commission, Washington, D. C.,
Testimony of William Nelson Cromwell continued. Pam.
Testimony of Richard L. Walker. Pamphlet.
U. S. Army, Chief of Ordinance, Washington, D. C.,
Report of Tests of Metals, etc. 1905.

## TRADE CATALOGUES.

Expanded Metal & Corrugated Bar Co., St. Louis, Mo. Pamphlet.
I. P. Morris Co., Philadelphia, Pa., Bulletin No. 2, Turbines and Centrifugal Pumps. Pamphlet.
H. M. Byllesby & Co., Chicago, Car Storage and Repair Shops of Ft. Smith, (Ark.) Light & Traction Co. Pamphlet.
Clinton Wire Cloth Co., Clinton, Mass., Clinton Fireproofing System. Pam.
Western Electric Co., Chicago, Bulletins of Motors. Four pamphlets.

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

## LIST OF OFFICERS FOR 1906



## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Electrical Section—S. G. McMeen, Chairman, generally the 2d Friday of the month, October to May, inclusive.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL.

PLATE I SITE OF THE ROOSEVELT DAM IN ARIZONA

# Journal of the Western Society of Engineers.

VOL. XI. AUGUST, 1906. NO. 4.

## HIGH PRESSURE SLUICING GATES.*

M. O. LEIGHTON.**

Among the government irrigation projects now under construction in the West there are three which require the erection of exceptionally high dams for the conservation of water. The United States Reclamation Service, which is performing this work, has been obliged to consider many unusual constructive features involving original studies. In some of this work there have been few or no precedents to serve as guides, and the result has been that a large number of engineering features are presented for discussion. I have selected from these the subject of high pressure sluicing gates for presentation to this society because it appears to involve the widest latitude of personal opinion among engineers. The three projects requiring these exceptionally high dams are, first, the Salt River project in Arizona, involving the construction of Roosevelt dam, 280 feet high, with an effective storage height of 230 feet, which represents the maximum head upon the sluicing gates at high water; second, the North Platte project, involving the construction of the Pathfinder dam in southeastern Wyoming, which will have a total height of 220 feet, with a head of 190 feet upon the gates at high water; and third, the Shoshone project in northern Wyoming, involving the construction of the Shoshone dam, the highest in the world, 308 feet, with a maximum head of 240 feet upon the gates.

These three dams are being equipped with outlets quite different from those installed in dams used for municipal water supply purposes in the East. Instead of the outlet towers and iron pipes, with appropriate valves, which are usually installed, these western dams have large tunnels which enter the canyon walls above the dams and open out below, leaving the structures themselves practically monoliths, or wedges between the canyon walls, without conduits or any other apertures through the masonry. The purpose of these large tunnels is to discharge greater amounts of water than is ordinarily

* This paper was compiled from Reports of Supervising Engineers U. S. Reclamation Service, and takes the place of Mr. Leighton's address before the Society, January 17, 1906.

**Assoc. M. Am. Soc. C. E. Engineer in Charge, Hydro-Economic Investigations, U. S. Reclamation Service.

required from reservoirs used for municipal water supply requirements. The outlet of the Wachusett reservoir in Massachusetts, for example, consists of four 48 in. cast iron pipes, provided with valves, the combined capacity of the pipes with valves wide open, and reservoir full being 2,500 cu. ft. per sec. For the purposes of irrigation, however, a greater discharge is necessary. The sluicing tunnel under the Roosevelt dam has a capacity at full reservoir of 10,000 cu. ft. per sec., or four times that of the Wachusett outlets. Therefore, if a system of 48 in. pipes were placed in the Roosevelt dam, similar to those in the Wachusett dam, it would require 14 pipes to discharge the amounts of water necessary. The total diameter of this number of 48 in. pipes is 56 ft. It should be borne in mind, however, that the Roosevelt dam is only 138 feet long at datum. Therefore, about 45 per cent. of the entire length of the dam would consist of apertures. The practical result of such an installation would be to honeycomb the structure at a section where great stability is most necessary.

The conditions are similar at the two other dams. They are short structures forming enormous reservoirs, out of which must be discharged great quantities of water. For this reason large sluicing tunnels which curve through the canyon walls have been installed in connection with all three of these dams. The installation of suitable gates to control the flow through these large tunnels has been a matter of considerable study upon the part of the engineers of the Reclamation Service.

At the present writing the details have been completed in the case of the sluicing gates for the Roosevelt dam. The type and general arrangement has been determined upon for the Shoshone dam, while the type of gate for the Pathfinder dam has not yet been finally selected, but various designs are being discussed, one of which will hereinafter be described.

In order that the most important features of the three dams under consideration may be well understood and compared with the structures already erected, the following table, in which such features are set forth, along with similar statements for the New Croton and Wachusett dams, is presented.

| | Roosevelt | Pathfinder | Shoshone | New Croton | Wachusett |
|---|---|---|---|---|---|
| Length at crest | 650 | 226 | 175 | 1168 | 850 |
| Height above foundation | 280 | 210 | 308 | 297 | 207 |
| Max. effective storage, hgt. | 230 | 190 | 240 | 157 | 185 |
| Thickness at base | 158 | 94 | 108 | 206 | 185 |
| Thickness at creast | 16 | 10 | 10 | 18 | 25 |
| Cu. yards of masonry | 350,000 | 53,000 | 69,000 | 833,000 | 280,000 |
| Cap. of rerervoir (million cu. feet) | 61,000 | 43,560 | 19,863 | 4,000 | 8,400 |
| Cost of dam | $2,000,000 | 600,000 | 700,000 | 7,600,000 | 2,000,000 |
| Cost of dam per million cu. feet stored | $32.80 | 13.78 | 35.25 | 1900.00 | 238.10 |

*Roosevelt Gates*: Plate I, the frontispiece, is an upstream view of the canyon across which the Roosevelt dam is being constructed.

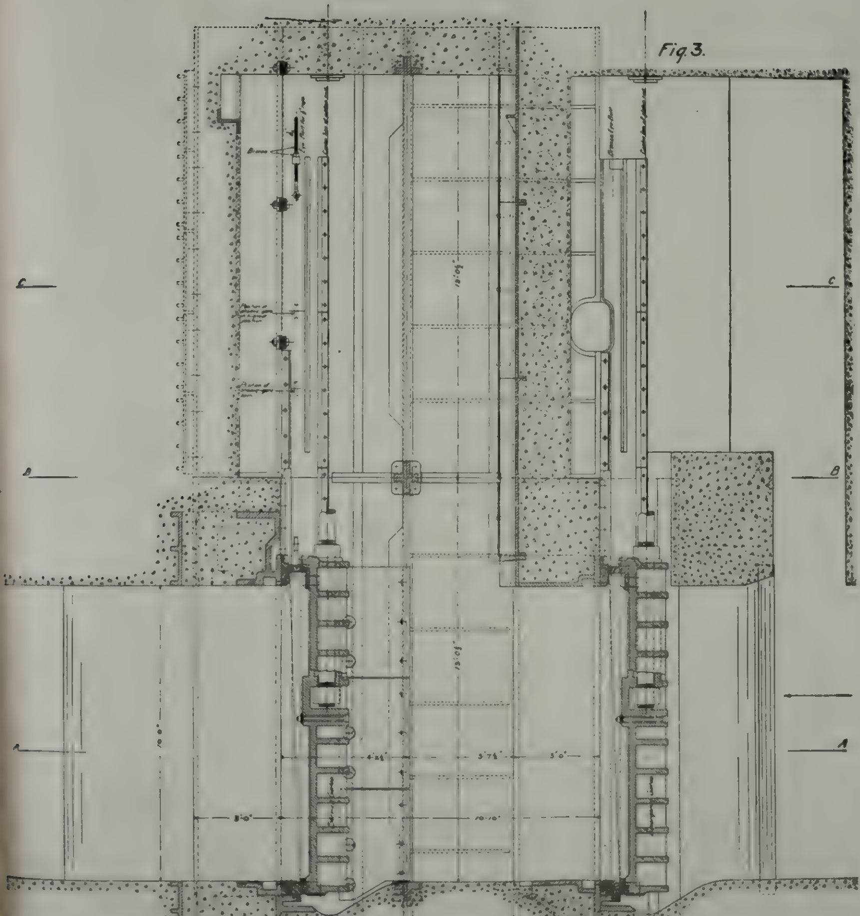
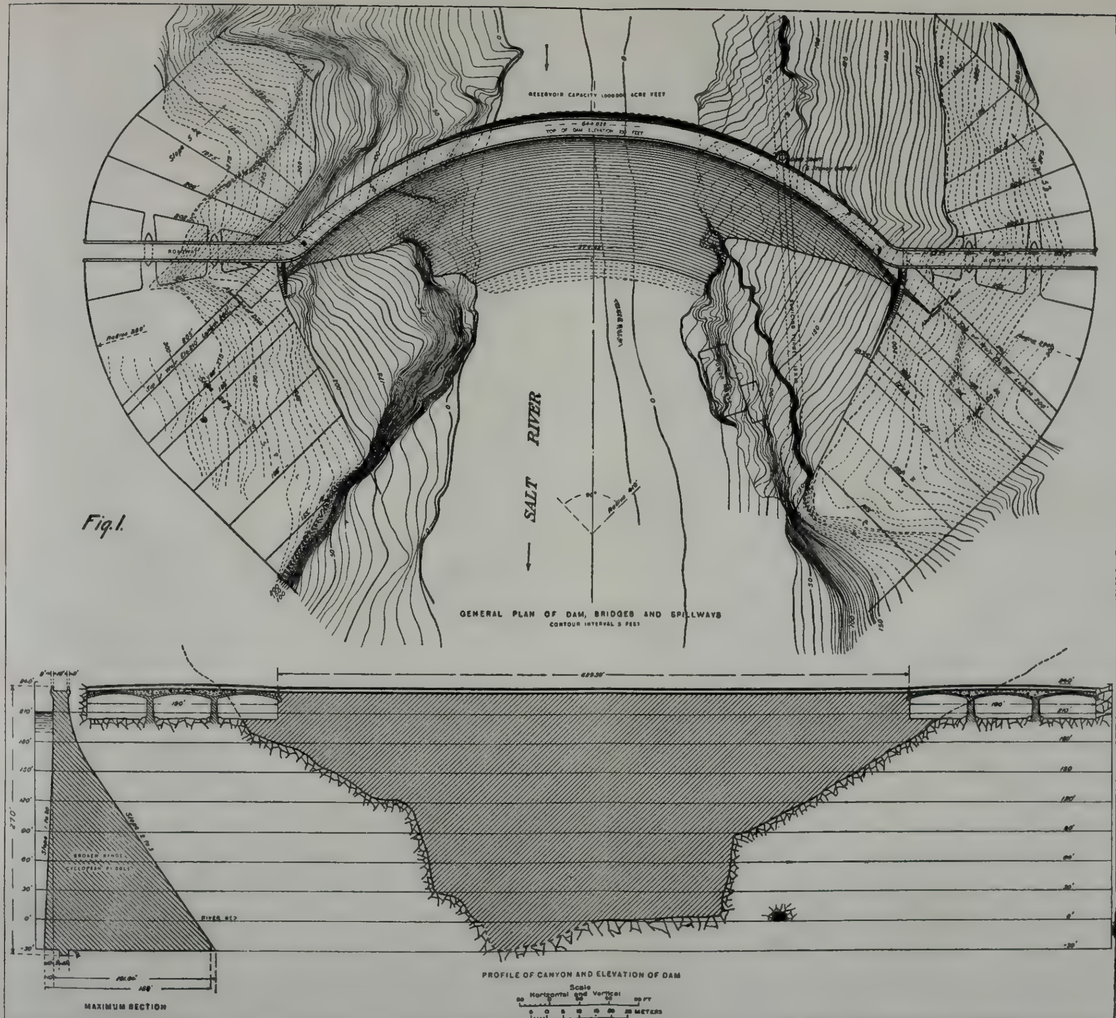


Fig. 3.
C
C
B
B
A
A

required fr
ments. Th
example, c
valves, the
and reserv
irrigation,
tunnel und
10,000 cu.
Therefore,
dam, simil
pipes to dis
eter of this
mind, how
datum. T
dam would
installation
great stabi
The con
structures
charged gr
tunnels wh
connection
gates to c
matter of
Reclamatio
At the p
of the slui
arrangeme
the type o
selected, b
hereinafter
In order
considerati
tures alrea
set forth,
Wachusett

Length at cr
Height above
Max. effectiv
Thickness at
Thickness at
Cu. yards of
Cap. of reser
(million cu
Cost of dam.
Cost of dam
cu. feet sto

*Rooseve*
of the can




GENERAL PLAN, ELEVATION AND SECTION OF THE ROOSEVELT DAM. SALT RIVER PROJECT, ARIZONA.

requi
ment
exan
valve
and
irrig
tunn
10,00
Ther
dam
pipe
eter
min
datu
dam
insta
grea
T
stru
char
tunr
conr
gate
mat
Rec
A
of t
arra
the
sele
here
I
con
ture
set
Wa

Len
Heig
Max
Thic
Thic
Cu.
Cap
(r
Cost
Cost
cu
I
of

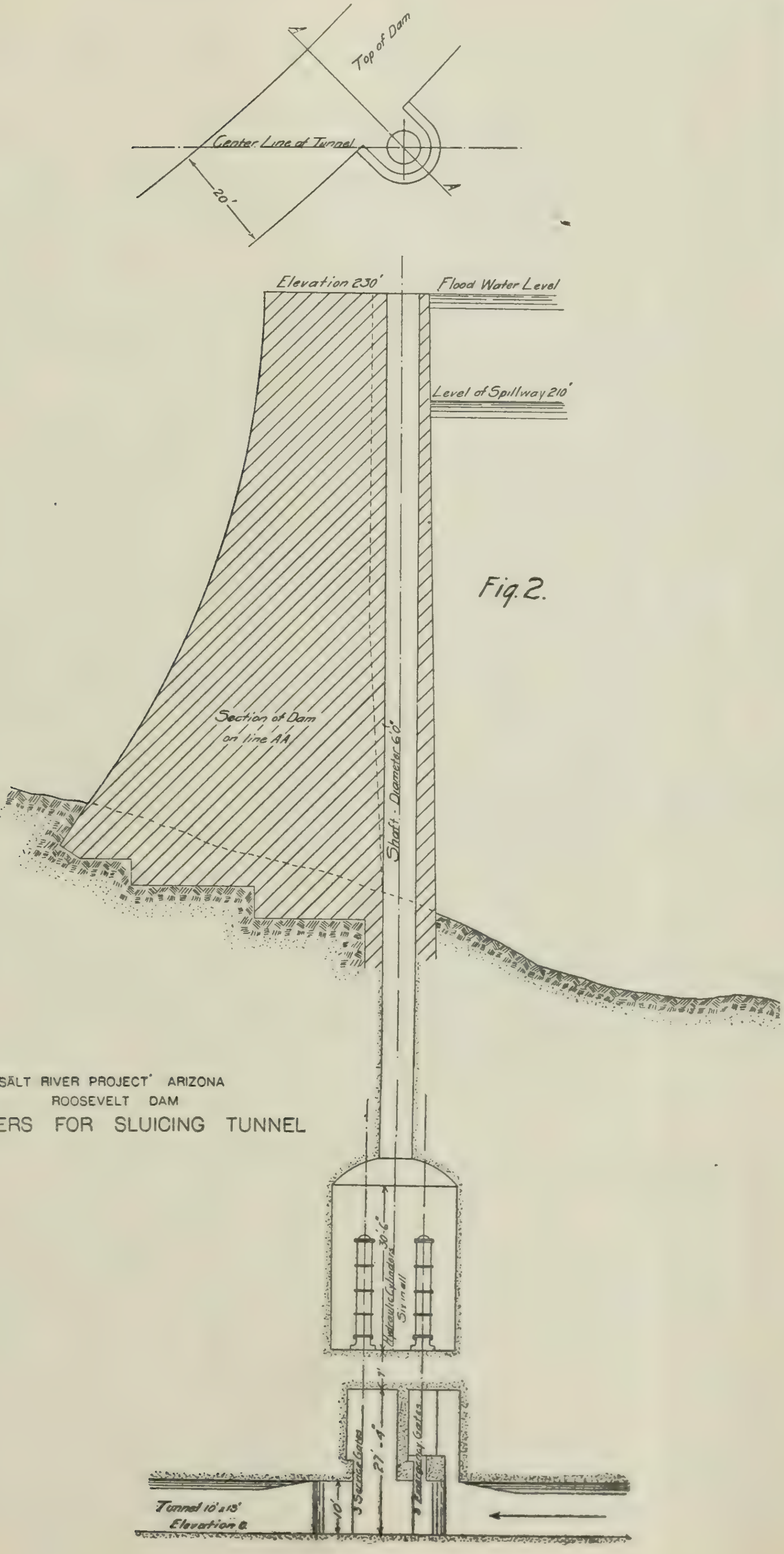



Fig. 2.

SALT RIVER PROJECT ARIZONA
ROOSEVELT DAM
CHAMBERS FOR SLUICING TUNNEL

The masonry will consist of the stone quarried from the walls of the canyon and from the spillway excavations. It is a tough, coarse-grained sandstone, with a specific gravity of about 2.5, and with a crushing strength of from 1,000 to 1,800 tons per sq. ft. The plan and maximum cross-section of dam and cross-section of canyon are shown on figure 1, while to the right of the canyon section at datum is indicated the position of the sluicing tunnel. This tunnel, which is carried through solid quartzite and sandstone, is 480 ft. long, 13 ft. wide, and 11 ft. high, and has a capacity, with the water in the reservoir at spillway elevation, of 10,000 cu. ft. per sec. In this tunnel are placed three sets of "Stony" gates, each set consisting of two in tandem, one being for service and one for emergency. These gates will be subject to a pressure of 100 lbs. per sq. in., or a total pressure of 800,000 pounds.

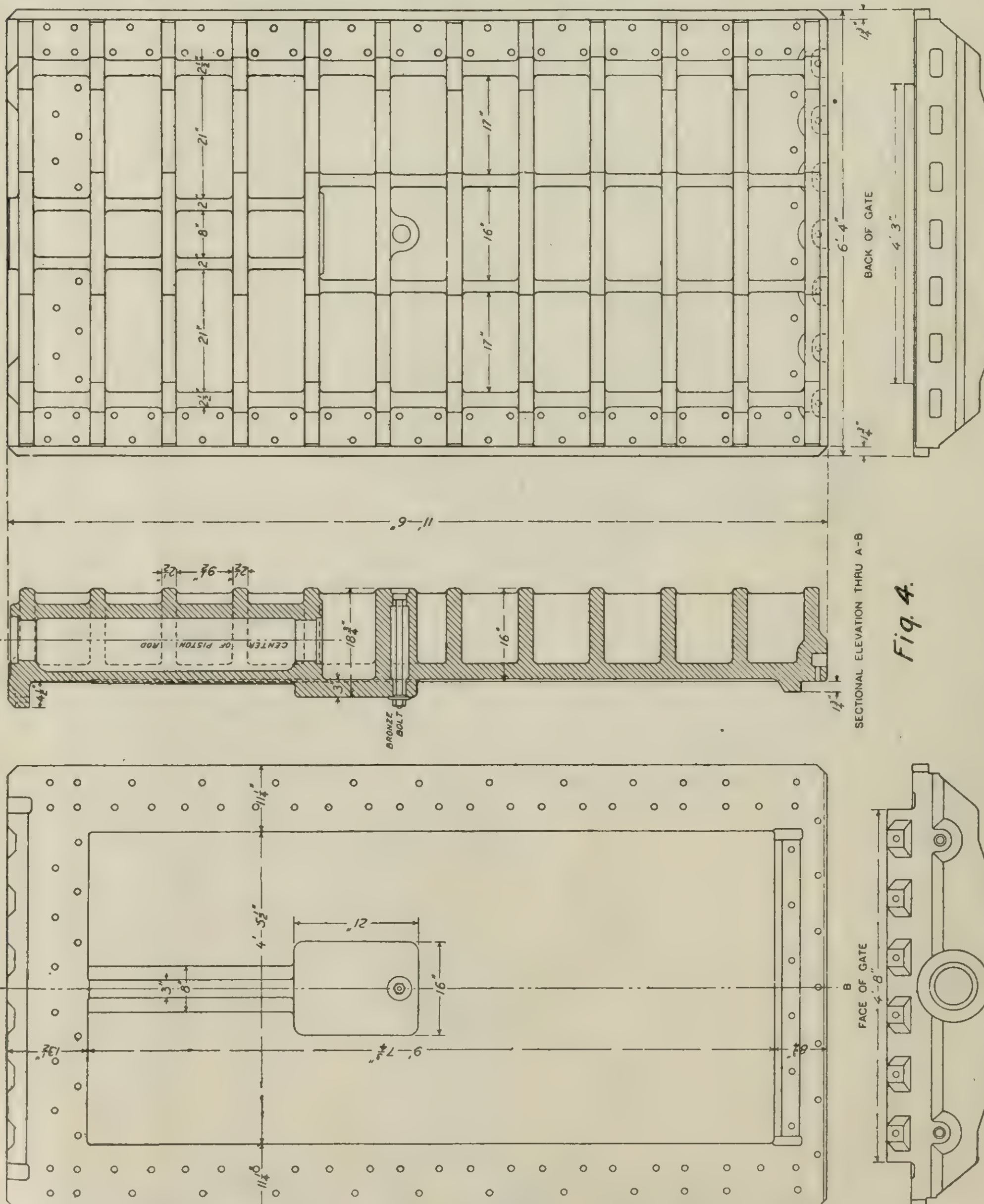



Fig. 4.

SLUICE GATES ROOSEVELT DAM

DETAILS OF GATE

The general relation of the sluicing tunnel gates and dam is shown in figure 2. It will be seen that the gate and cylinder chambers are excavated in the solid rock above the tunnel line. At this point the dam mounts up on the side walls of the canyon, so that the cylinder chamber is below the foundations of the dam, and the monolithic nature of the dam structure is preserved. It will be seen from an examination of figure 1, that the gate shaft is excavated back of the upper face of the dam and is continued above the ground surface by a masonry tower, which is contiguous with the dam structure.

At figure 3 is shown a section through the center of one of the chambers. It shows the service and emergency gates in closed position. The bronze bearings of the gate leaf and gate seat are shown and it should be noted that the lower frame bearing extends out farther than the upper, while the reverse is true of the upper and lower leaf bearings. The bearings on the sides of the gate and frame are properly tapered, so that when the gate descends into the closed position, these bearings give to the gate a slight backward thrust as it closes, making a wedged tight joint along the bearing edges. Attention should also be given in figure 3 to the indicated positions of the roller sheave at various gate heights, together with the position of the eye bolt to which the bronze rope which operates the roller sheave is attached.

In figure 4 are assembled the various details of the gate. The gate leaves are of cast iron, having a tensile strength of not less than 20,000 lbs. per sq. in. The face of the gate leaf and its brace ribs are cast in one piece, both being 2½ in. in thickness. The bronze shafting, 6⅝ in. in diameter, penetrates five of the brace ribs and is secured by a heavy nut just above the center of the gate leaf. It will be noted that vertical ribs for reinforcement of the gate leaf pass along beside the core of the bronze shafting 8 in. apart to the shaft nut, and below this point continue 16 in. apart to the foot of the gate leaf. These vertical ribs are cast with the gate leaf. A plate is attached to the face of the gate and secured by a bolt, shown in the longitudinal section. This plate can be removed at any time and access be had from the front of the gate to the bronze nut which holds the gate shafting.

Figure 5 consists of assembled drawings of the gate seat which will be bolted to the front of the gate leaf in the manner indicated. This false face is made of bronze, tapers from top to bottom about 1 in 30 and is designed to serve as a bearing against the seat. The latter is faced with a similar bronze bearing, tapered in the direction opposite that of the gate face, the two meeting in a tight joint when the gate is closed, as shown in the sectional elevation.

The face and seat bearings are of bronze, the former having the formula: Copper 83.50, Lead 8.10, Zinc 4.50, Tin 4.90, and the latter, Copper 81.80, Lead 4.90, Zinc 5.30 and Tin 7.10. These formulas provide for a face bearing much softer than that of the seat and therefore the former will wear down with the continued use of

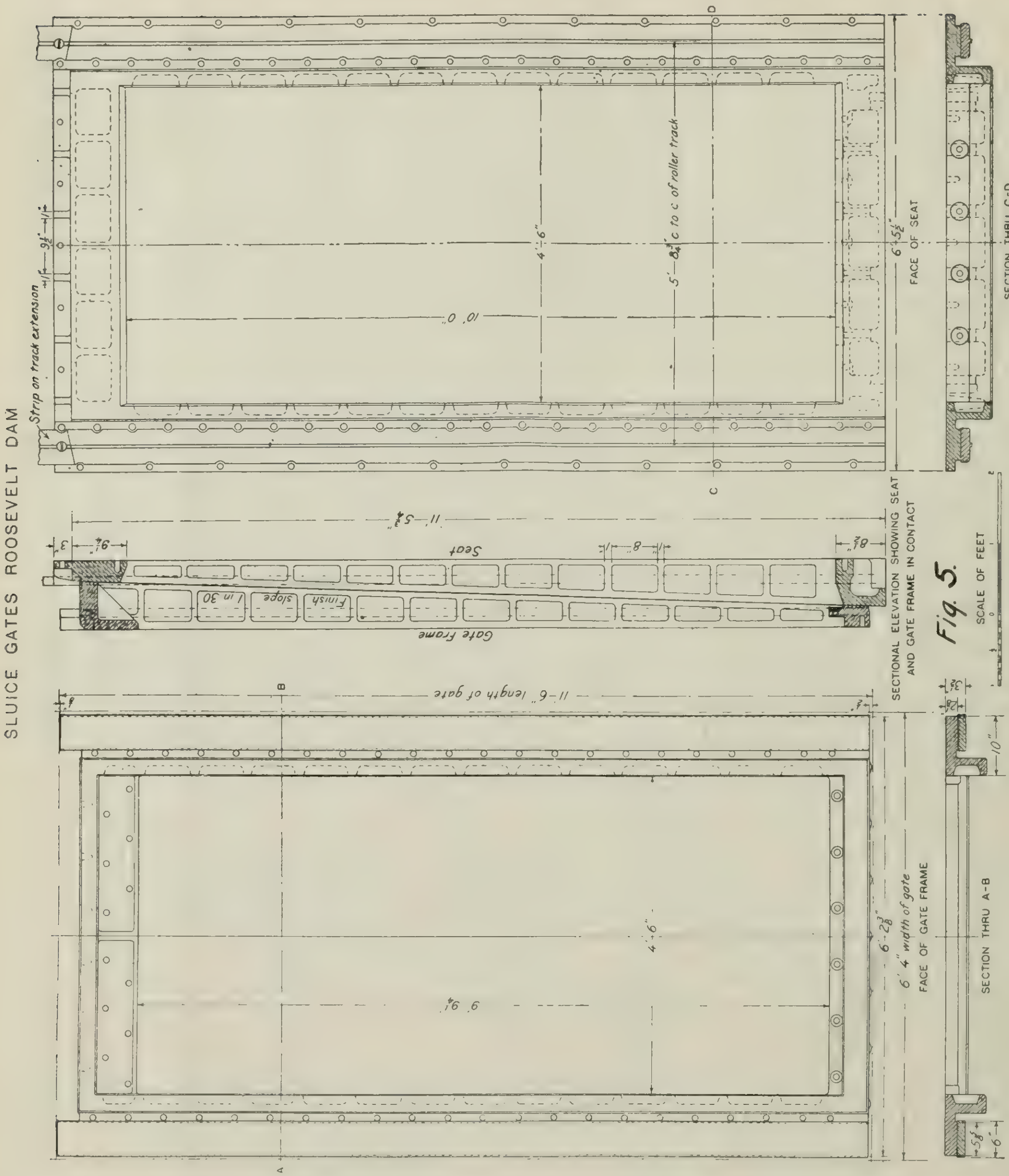



Fig. 5

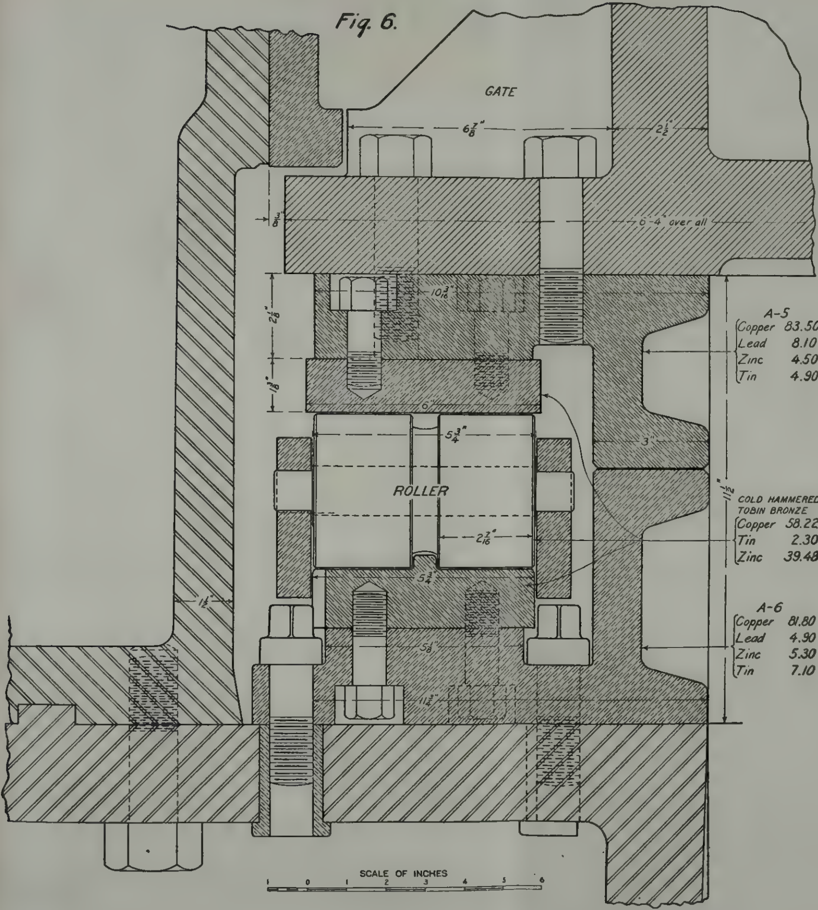
DETAILS OF SEAT AND GATE FRAME

the gate. The result will be that the gate in closed position will, after continued use, rest lower and lower upon the seat, the final position of the gate at closure being 4 in. below that of the initial closure.

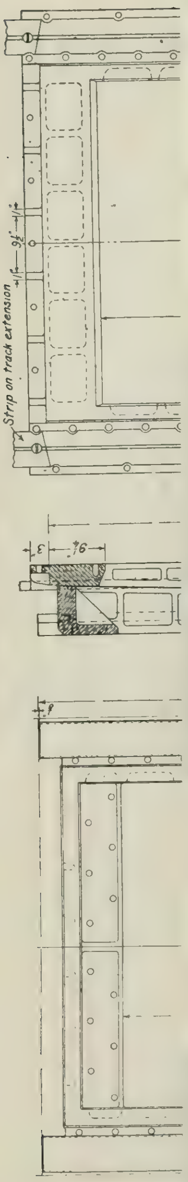
A horizontal section along the side jams and the roller sheave, showing the closure of the gates, is at figure 6. The dividing line between the gate leaf bearings and the roller sheave and jam bearings is accentuated by the extra heavy dark line. The bearings consist, first, of the tapered extension plates of the bronze false face and bronze seat, described in the preceding paragraph. Attached to the outer portions of these two bronze bearings so fashioned as to bear upon the roller sheave are interposed two tobin bronze plates. The rollers and bearing plates are of cold hammered Tobin bronze of the formula: Copper 58.22, Tin 2.30, and Zinc 39.48. The rollers are

SLUICE GATES ROOSEVELT DAM

*Fig. 6.*




HORIZONTAL SECTION THRU GATE, GATE-FRAME, SEAT, ETC.

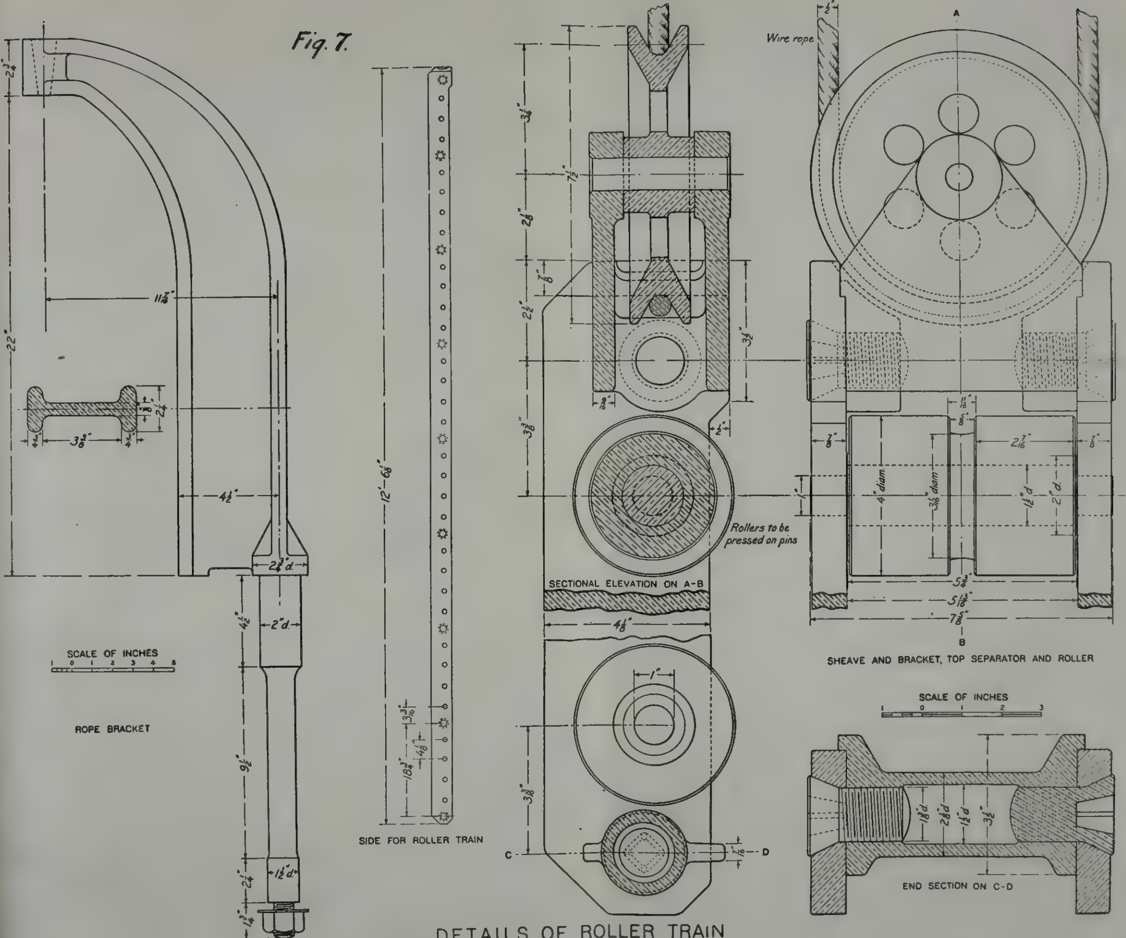



SLUICE GATES ROOSEVELT DAM

the gate. T
after contin
sition of th
closure.

A horizo
showing the
between the
ings is acce
sist, first, of
bronze seat,
outer portio
upon the ro
rollers and l
formula: (

SLUICE GATES ROOSEVELT DAM




DETAILS OF ROLLER TRAIN


SLUICE GATES ROOSEVELT DAM

the
afte
sitio
clos
A
sho
bet
ing
sist
bro
out
upo
roll
forı

4 in. in diameter and 5¾ in. long over all. It will be seen from the drawing that the rollers have ⅝ in. recesses into which fits the tongue of the track bar. This reduces the actual bearing surface of the rollers to 4 11/16 in.

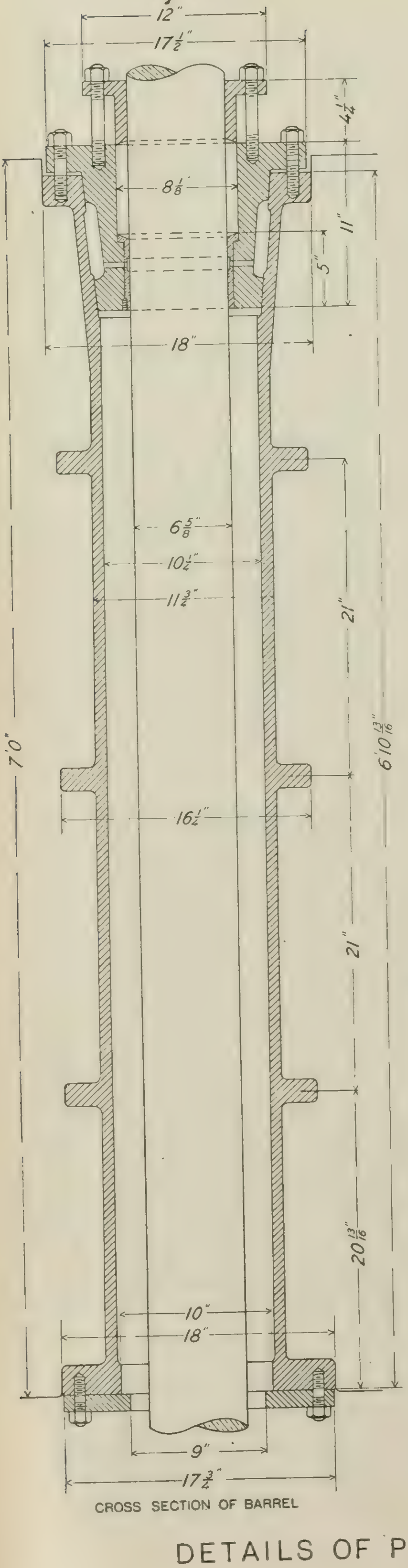
The determination of the proper dimensions for these rollers proved to be exceedingly troublesome and there was emphasized the fact that there is a paucity of reliable data concerning the load which bronze rollers and roller bearings will support without taking a permanent set. In preparing these specifications, the Board of Engineers, consisting of Messrs. Geo. Y. Wisner, W. H. Sanders, and Louis C. Hill, recognized the fact that the data as to the supporting strength of bronze is not satisfactory and recommended that, as soon as the contractor's machine shop was at the disposal of the supervising engineer, careful experiments be made with rollers similar to those specified, with loads equal to the maximum likely to be put upon rollers in actual practice. These investigations developed the fact that the best bronze will not support as heavy loads as usually stated by the manufacturers. The original plans for the Salt River gate rollers were based upon the most reliable data that could be collected, but the results of the shop tests demonstrated that it would be absolutely necessary to increase the length of the rollers and the width of the roller bearings about 2½ in. over that originally calculated, from the then existing data. This increase involved an expense of about $20,000.00 more than that originally estimated.

In figure 6 are shown the details of the roller sheave. It will be seen that each sheave contains 31 bronze rollers set into the bronze roller train in sets of four, the distance between the centers of the roller axles being 4⅛ in. The formula for the bronze used for roller trains is the same as that for the gate seat. These trains are held by bronze separators secured by countersunk bronze screws, said separators being a trifle longer than the rollers, in order to provide for free movement of the latter. The countersunk screws are readily removed so that, if necessary, the entire roller sheave may be taken apart and adjusted or repaired. There are also shown in figure 7 the terminal grooved bronze roller at the top of the sheave through which the bronze rope passes which raises or lowers the sheave at a velocity of one-half of that at which the gate leaf is raised or lowered; also further details of the roller train and the rope holder that is attached to the top of the gate. It will be noted in connection with all of these drawings, that all bearings and removable bolts are of bronze and where such screws and bolts are set in other metal, bronze bushings and seats are provided.

The relative positions of the gates and the hydraulic cylinders which serve to raise the gates are shown in figure 8. These cylinders will be operated with water taken from the power canal, the head being about 200 feet. The cylinders are constructed of cast iron of sufficient strength to operate under a pressure of 600 lbs. per sq. in.

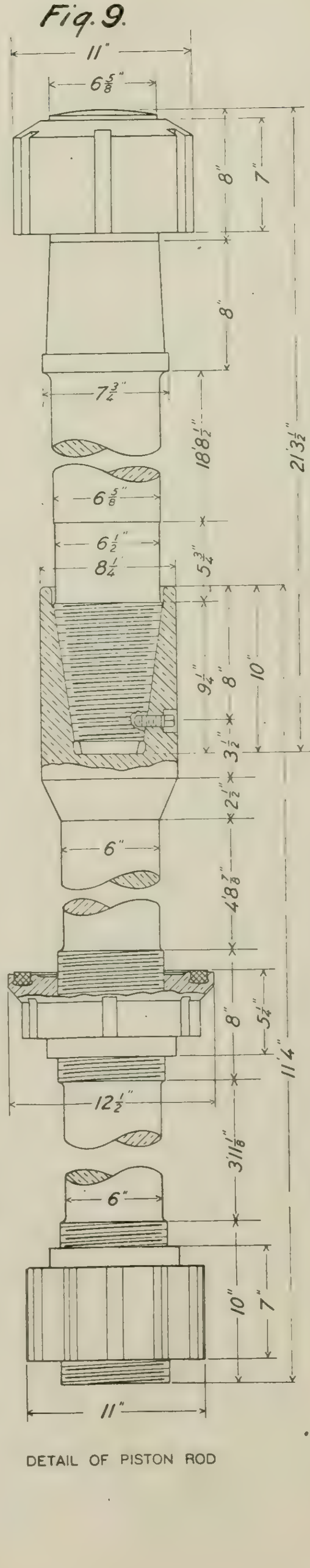
SLUICE GATES ROOSEVELT DAM

Fig. 10.



CROSS SECTION OF BARREL

Fig. 9.



DETAIL OF PISTON ROD

Fig. 8.

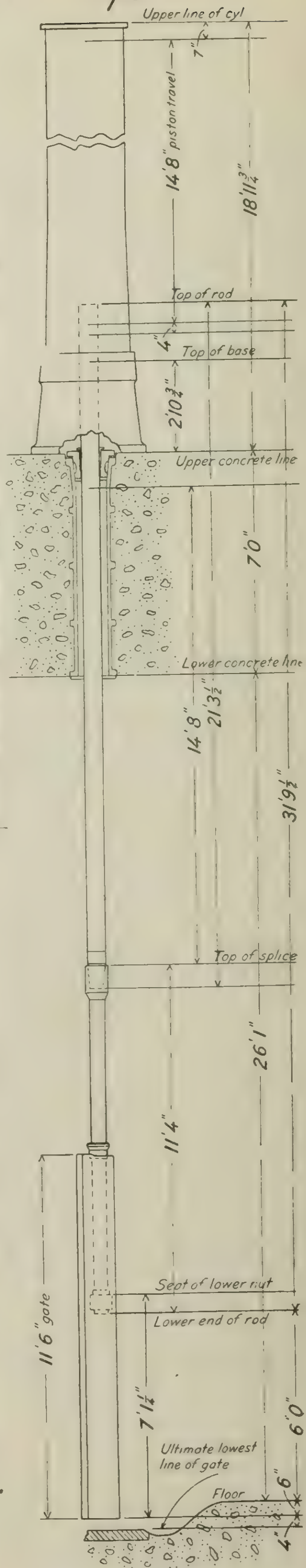


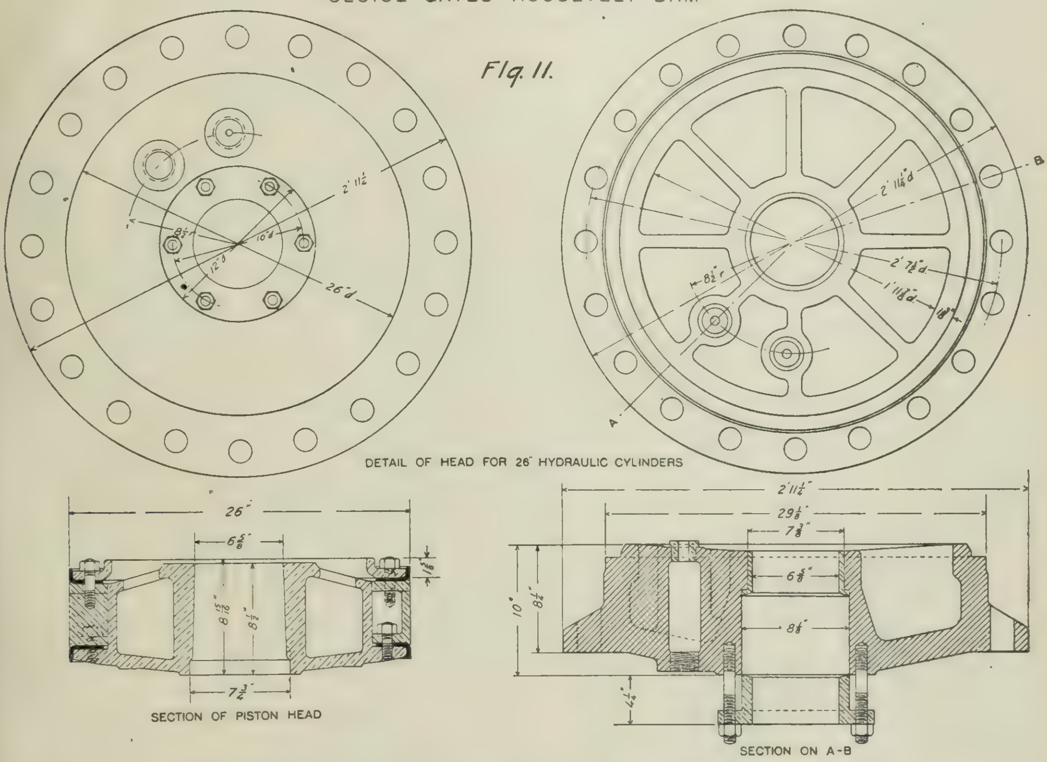

DIAGRAM SHOWING BARREL, PISTON ROD AND GATE IN POSITION

# DETAILS OF PISTON ROD AND BARREL

They are lined with a brass sheath, 5-16 in. in thickness, which reduces the effective diameter of the cylinder to 26 in. The cylinder is 18 ft. 11¾ in. long, while the stroke of the piston will be 14 ft. 8 in.

Figures 9 and 10 show further details of the piston and rod barrel set in the concrete floor between the gate and cylinder chambers, while on figure 11 are presented the details of the piston head.

SLUICE GATES ROOSEVELT DAM




DETAILS OF PISTON AND CYLINDER HEADS

Figure 12 shows the arrangement of the automatic shut-off. Drawing "A" is a vertical section of the valve, the details of which explain themselves. It will be seen in drawing "B" that there are two of these valves connected, as explained in the note, by a piece of 2 in. pipe. These valves are operated by small bronze plungers, entering the upper and lower cylinder heads. The operation of these automatic shut-offs is as follows: When the piston approaches its lowest position, it presses down the small plunger of lower cylinder head. This closes the lower valve and stops further egress of water and the piston comes to a standstill. If the piston, on account of leakage around the piston should continue to go down by the weight of the gate, etc., a further fraction of an inch until it reaches a stopping, the presence of the spring in the valve will prevent a breakage in the mechanism.

If the engineer wishes to raise the piston from its lowest position, the pressure water enters the lower valve from above, presses the valve open slightly, the piston begins to raise, the valve opens fully and the piston goes up; if pressure water is continued to be supplied

until the piston comes in contact with the plunger of upper cylinder head, then the piston will press the plunger upward, thus closing the upper valve, preventing further inlet of water below the piston and the piston comes to a standstill. By introducing the pressure water above piston, the water from below piston will open the upper valve slightly by compressing the spring, the piston goes down, the valve opens more, and the piston moves down until the pressure water is shut off, or until the piston reaches the plunger of lower piston head.

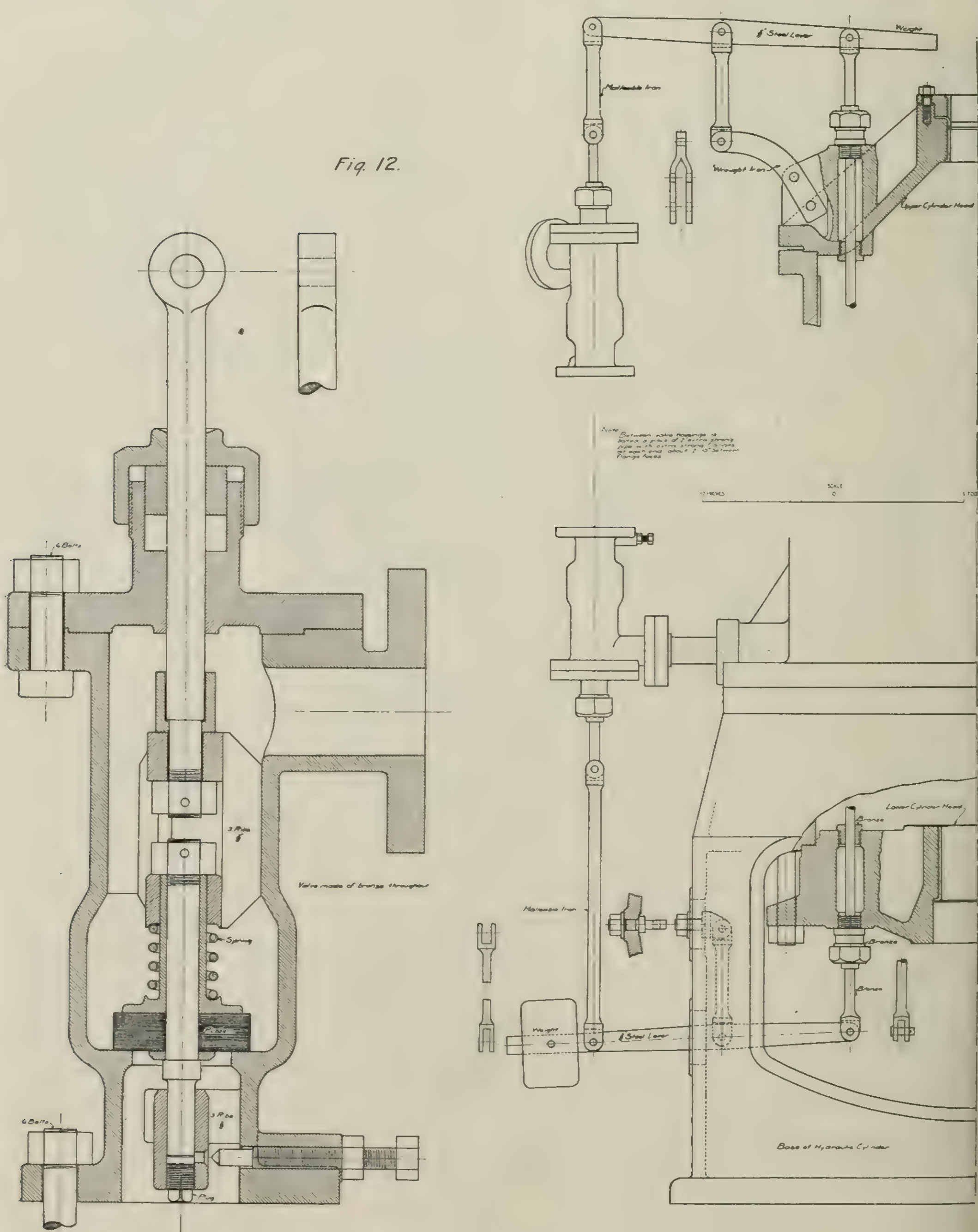



Fig. 12.

## "WHAT DEGREE OF ACCURACY IS FEASIBLE AND NECESSARY IN WIRING CALCULATIONS?"

ALBERT SCHEIBLE, M. W. S. E.

*Presented before the Electrical Section, April 20, 1906.*

My presence before you to-night is due chiefly to two causes, one being the persistent optimism of your chairman, Mr. McMeen, who maintained that on only six days' notice I could cook up a paper worth discussing; the other is the belief that, in certain lines of figuring, electrical men do not strike the common-sense mean between the crude approximation that allows for wide variations of practice, and the exactness which can correspond only to the far greater precision of laboratory conditions. At first glance it might seem as if over-exactness could do no harm, but, if other factors are so indefinite as to nullify the apparent precision, then the excess of exactness not only means a waste of time in figuring (with the temptation to save the time by guessing), but may also give out a misleading impression as to the closeness of the calculated result.

For instance, if one factor in a formula is known to the one-hundredth of 1 per cent. and calculated to that degree of precision, the natural assumption is that the result will be accurate to the same degree. But what if another factor in the same formula is determinable only to an accuracy of 1 or 2 per cent.?

Take, for example, the first of the formulas published by the General Electric Company for calculations on any system of electrical distribution, due, I believe, to Mr. E. J. Berg:

$$\text{C. M.} = \frac{D \times W}{P \times E^2} \times K$$

where D = Distance (one way) in feet
W = Watts delivered
P = Per cent. loss in line of W
E = Voltage at delivering end
and K = 2160 is a constant for continuous current
= 2400 for single-phase, all lights
= 1200 for 3 wire 3 phase, all lights
= 1500 for 3 wire 3 phase, motors and lights

Here the result of K for continuous current is 2160, and would have been 1080 if the total length of the wire had been taken instead of the one-way distance, this general formula being an enlargement of the more limited formula used in direct current figuring for nearly a score of years:

$$\text{C. M.} = \frac{\text{Feet} \times 2 \times \text{Amperes} \times K}{\text{Volts Lost}}$$

where K is still the mil-foot resistance of copper.

Or, better still, let us take an inverted form of the continuous current formula:

$$\text{Volts Lost} = \frac{\text{Feet} \times 2 \times \text{Amperes} \times \text{K}}{\text{Circulars Mils}}$$

Here the delivered amperes may be assumed to any desired closeness, leaving the exactness of the result to depend on the other three factors. Of these the circular mils are given by the commonly used table to an average exactness of *one-hundredth of one per cent.*, and I have usually found the circular mil figures used to the last place, instead of being approximated. Such an accuracy in the commercial sizes of wire is out of the question, it being more reasonable to expect variations of 1 per cent. in the same. Abbott, in his proposed standard specifications for hard-drawn copper telephone wires, provides that the weight of the same shall not vary by more than 2 per cent. from the specified figure, and allowing for variations in the specific gravity, this would still imply their coming within 2 per cent. of the desired circular mil cross-section, or 200 times the error allowed in using circular mil figures to the last place.

As for the length of the wire, the common methods of estimating line distances on streets, allowing for variations in sag and in the tilting of corner poles, would make a difference of two feet in a thousand a neglible error; and, in estimating lengths from a building plan, who would claim to come closer than within 2½ inches on a hundred feet of wiring? Either of these means a possible error of one-fifth of 1 per cent. Some of you practical men would probably want to double or treble this allowable error.

The third factor is the mil-foot resistance of copper. On this we should expect to find a general unanimity, but a glance through various formulas and tables shows that this is not the case. When Dr. Matthiessen made his memorable tests on the conductivity of copper, he did not attempt to average the same, so, instead of establishing *one* standard of resistance for pure copper, he repeated several slightly different ones. To overcome this uncertainty, the American Institute of Electrical Engineers appointed a committee whose report, as accepted in 1893,[1] fixed a definite standard, corresponding to a value of 10.35 ohms for the mil-foot resistance of pure copper at 20° C. (or about 68° F.).

While the work of Dr. Matthiessen, as thus interpreted by the American Institute committee, has since then formed the accepted basis for calculations, it was soon shown that copper of even greater purity and higher density than that used by Matthiessen could be obtained, so that a conductivity of 102 per cent. and even 105 per cent. of the standard has been reached.

However, commercial copper does not usually reach Matthiessen's

[1] Transactions of the American Institute of Electrical Engineers, Vol. X, 1893.

standard of conductivity, hence safe calculations demand the use of a higher figure than 10.35 for the commercial mil-foot resistance. The figure actually used varies with different writers both here and abroad. Thus in England, Fowler's "Electrical Engineer's Year Book for 1906" gives it as 10.41, while Crapper's "Electric and Magnetic Circuits" uses 10.81 and Dawson, in "The Engineering Electric Traction Pocket Book," gives 10.8. In this country Professor Crocker, in the second volume of his work on Electric Lighting, implies a value of 10.56, while Abbott's specifications for copper telephone wire imply a value of 10.63. Other American writers differ as follows:

D. C. and J. P. Jackson: "Elementary Book on Electricity and Magnetism" .......................................... 10.50
Thomas G. Grier: "Notebook of Wiring Tables" .......... 10.60
H. A. Foster: "Electrical Engineers' Pocket Book" ........ 10.81
International Correspondence Schools: ..................... 10.80
Cecil P. Poole: "The Wiring Handbook" ................. 11.00
E. J. Borg (In tables published by the General Electric Company, October 26, 1896) .............................. 10.80
"Modern Engineering Practice" (American School of Correspondence) ......... ............................... 10.80

The values given by different authorities, therefore, range from 10.41 to 11, the more common figures being 10.5 as used by Perrine and the Jacksons, 10.8, used by Berg and the International Correspondence Schools, and 11, used by Bell and Poole. The reasons given for adopting these figures vary somewhat, and some of the most prominent writers even suggest more than one figure! Thus Professor Crocker on pages 5 and 9 of his second volume on "Electric Lighting" makes these statementss: "The resistance of any copper wire at 20° C., (or 68° F.), according to Matthiessen's standard, may be calculated by the following simple formula:

$$R = \frac{10.35\, l}{d^2}$$

It is customary to specify in plans and contracts that copper for electrical purposes shall have a conductivity not less than 98 per cent. of Matthiessen's standard. Assuming a conductivity of only 98 per cent., this would mean a value of 10.56 for the mil-foot resistance, yet on page 233 of the same volume we find Berg's formulas based on a value of 10.8, a figure 2.23 per cent. higher than that previously given.

Louis Bell in the 1906 edition of his "Electric Transmission of Power" (page 486) says: "At present the best grades of copper wire have a conductivity of fully 98 per cent. of that of the chemically pure metal, and even this figure is not infrequently exceeded" and again (p. 509): "The actual value of the mil-foot constant at ordinary temperature is approximately 10.8, but is here taken as 11 ohms to take account of the ordinary contingencies of irregular

diameter, slight variation in conductivity, and the effect of hard drawing." So also in his earlier volume on "Power Distribution for Electric Railroads" (p. 25) Dr. Bell uses 11 as "the desirable value of the mil-foot resistance, allowing for the ordinary contingencies of temperature, joints, etc."

On the other hand, Perrine apparently thinks that 10.5 allows for commercial impurities, since he says in his work on "Conductors for Electrical Distribution' (p. 132): "For the purpose of transmitting large amounts of electrical energy, use is made of heavy conductors of copper having a specific resistance at a temperature of 75° F., expressed in terms of the resistance per mil-foot as 10.5 ohms." So also the statement of the two Professors Jackson in the book already mentioned (p. 383): "The resistance of a commercial wire which has a cross-section of one circular-mil and a length of one foot (that is, one mil-foot) is about 10.5 ohms at ordinary temperatures."

Mershon in the ohmic resistance table accompanying his chart for alternating current calculations (Query: to what degree of accuracy can such charts be used?) makes no mention of the temperature or degree of purity, but the resistance figures given by him approximate those for Matthiessen's standard conductivity at 68° F., corresponding to a mil-foot value of about 10.4. This table of Mershon's is reprinted by Foster in his "Electrical Engineers' Pocket Book" (p. 137), yet the same work uses 10.81 in a number of formulas, saying (p. 99), "The resistance of 1 mil-foot of 96 per cent. conductivity copper wire at 70° F. is 10.81 ohms."

Poole in "The Wiring Handbook" admits it as a common custom to use values of 10.5 or 10.75, but thinks the actual length of wire used will be several per cent. greater than that estimated, since he says (p. 33): "The resistance per mil-foot of copper wire at about 70° F. is 10.6 to 10.8 ohms; the slightly larger value of 11 is used here in order to make a little allowance for the discrepancy between the actual and the calculated length of a stretch of wire." Just why this discrepancy in length should always be an additive one is not stated.

Several textbooks of the International Correspondence Schools use 10.8 on the ground of its being the mil-foot resistance of pure copper at 75° F., and quite consistently quote Berg's alternating current formulas based on the same figure.

Over in England, Ellis H. Crapper, who is at the head of the Electrical Engineering Department in the University College at Sheffield, interprets the work of the British committee on Copper Conductors as fixing the mil-foot resistance of annealed, high-conductivity, commercial copper (at 60° F.) at 10.2044 standard ohms, which would correspond to abolut 10.41 ohms at 70°. However, in the same work ("Electric and Magnetic Circuits," pages 355 and 135) he says: "The resistance of 1 foot of wire, 1 nil in diameter, is 10.81 ohms at 70″ F."

Here again there seems to be a discrepancy in one and the same

textbook, though not as great as that between the values taken by prominent American writers, which differ by fully 4½ per cent. Probably every work that I have mentioned has a large number of followers who swear by it without stopping to check up the basis of the formulas or tables. Many, and perhaps most, of the calculations for which such formulas and tables are used may be of such a nature that an error of one or two per cent is not serious; but does that warrant the wide discrepancies just mentioned or the waste of time implied by using circular-mil or resistance tables to their last point? Are we not justified in expecting prominent writers to agree closely on the value assigned for constants in widely applicable formulas? And if the conductivity, owing to differences in purity and hardness, may vary (say) one per cent, while the estimable lengths may vary from 1-5 to ½ of one per cent, why should we attempt to go beyond an accuracy of (say) 1-10 of one per cent in the other factors used with the same? Would it not be more common-sense for all practical work to supplement our Circular Mil and Ohmic Resistance tables with columns of approximations for ordinary use?

| Wire Size | Circular Mils | | Ohmic Resistance per 1000 ft. Pure Annealed Copper at 68° F. | |
|---|---|---|---|---|
| B. & S. Gauge | Exact | Proximate | Exact | Proximate |
| 4/0 | 211600 | 212000 | 0.04893 | 0.049 |
| 3/0 | 167805 | 168000 | 0.06170 | 0.062 |
| 2/0 | 133079 | 133100 | 0.07780 | 0.078 |
| 0 | 105535 | 105500 | 0.09811 | 0.098 |
| 1 | 83694 | 83700 | 0.12370 | 0.124 |
| 2 | 66373 | 66400 | 0.15600 | 0.156 |
| 3 | 52634 | 52600 | 0.19670 | 0.197 |
| 4 | 41743 | 41700 | 0.24800 | 0.248 |
| 5 | 33102 | 33100 | 0.31280 | 0.313 |
| 6 | 26251 | 26250 | 0.39440 | 0.394 |
| 7 | 20871 | 20900 | 0.49730 | 0.497 |
| 8 | 16510 | 16500 | 0.62710 | 0.627 |
| 10 | 10382 | 10400 | 0.99720 | 0.997 |
| 12 | 6530 | 6530 | 1.58600 | 1.590 |
| 14 | 4107 | 4100 | 2.52100 | 2.520 |

Or, in the formulas where commercial figures are concerned, ought we not to waive the laboratory refinements and content ourselves with a more reasonable degree of accuracy? Take, for example. Abbott's specification of copper telephone wire* that "the weight per mile should be determined by carefully weighing 2 per cent of the number of coils called for in the contract, and that the weight thus obtained shall correspond within 2 per cent, on either side of the result given in the following formula:

[1] Quoted in Miller's "American Telephone Practice," 4th edition, p. 764.

$$\text{Weight per mile} = \frac{\text{Circular Mils}}{62.567}$$

Changing this to $\frac{\text{C. M.}}{62.6}$ introduces an error of less than 1/20 of 1%, and expedites its use for work involving an admitted variation of 2%. Of course I am a believer in exactness, but not in the over-exactness which may be nullified by the variations of practice, nor in the wasting of time which often leads to the substitution of mere guess-work for the calculating, hence my raising this point.

Many of you will know of other formulas where the same arguments may apply, so my question-topic resolves itself into these three which seem to me timely questions for discussion:

(1) Why should there be any dicrepancy in the values of constants used for common calculations?

(2) To what degree of accuracy can wiring be figured?

(3) Ought not approximate constants and tables to be used more freely for such calculations?

DISCUSSION

*P. Junkersfeld*—M. W. S. E.—Mr. Scheible has raised a number of questions well worth a good deal of attention.

Over-exactness is something that undoubtedly is the cause of much waste of time in a great many respects, but is something about which we must not get careless. We must determine when and where. We must remember that conditions vary widely. These various conditions frequently offset, a great many times, the refinements which might be dispensed with in particular cases.

*George A. Damon*—M. W. S. E.—It is always interesting to meet our old friend, Ohm's Law in any of its many forms. Every young electrical engineer should, of course, be intimately acquainted with this law in all of its forms, and for that reason I believe it good policy for a young man in starting out in making calculations involving Ohms Law to go to the extreme of refinement, rather than to begin to guess too early in his career. The faculty of reaching an engineering conclusion by guess, or by an approximation, is something which sould be approached with a great deal of caution.

In connection with wiring calculations, I do believe that the best results are sometimes obtained by what might be called engineering "finesse," rather than by means of careful calculations. For instance, take the feeder system for an electric railroad. Here is a situation in which you can make exact engineering assumptions and figure out the answer to a nicety, and get just the diameter and the length of the feeder which should be provided to run the railroad, and when you get throught it may be possible to put in half as much feeder, and the road will still be able to operate. The fact is that the amount of feeder is often determined not so much from the

calculations of losses and by Ohm's Law as it is by how much money there is available to build the road. Therefore, when an engineer starts out to get a result of this kind, he should be posted as to the financial conditions, as well as to the physical ones; then he will be in the best position to make the proper assumptions.

In calculating a feeder system, it is necessary to assume a percentage of loss. A percentage of loss upon what? Upon the maximum current that is going to pass over the feeder, or upon the average current? If you have a variable load, and figure average current, you may be surprised to see what a small feeder will answer the purpose. If you figure upon the maximum current, the size may be prohibitive, from a financial standpoint. Again, what is the allowable per cent of loss, as this assumption, of course, will have a very material influence on the answer. The young engineer is liable to figure that he will allow a 5 per cent loss upon the maximum current. If he does, the requirements of his feeder system will probably bankrupt the promoter. On the other hand, an assumption of 20 per cent loss on the average current would result in such a small feeder that the lights in the cars at the end of the feeder would be dim, and the passengers would be unable to read. Between these two extremes a balance must be found. In handling such a problem, it would be well to figure it out in several ways, and get the limitations, and thus be in a position to use good judgment as to the amount of feeder to recommend.

In the approximate table of wire sizes which Mr. Scheible has shown, it strikes me that his table does not get far enough away from the standard table to be of any particular use. We have all noticed, of course, that the cross section area in circular mils of a wire is about double every third size. For instance a No. 0000 wire is about twice the size of a single 0 wire. It seems to me that we might take advantage of this fact, and make our table read in round numbers; for instance, No. 0000 wire—200,000 C. M.; No. 0 wire—100,000 C. M., etc.

There is one thing in connection with the use of the formula which Mr. Scheible has not brought out, that is, the purity of the wire. The value of the resistance of a mil-foot as ordinarily specified is for wire composed of 98 per cent. pure metal. Personally I have actually never had the purity of copper measured but once, although we have bought a great deal of copper. We have always assumed that we could get it as pure as specified. We did, however, measure it once, and the reports showed that it was not quite 98 per cent. pure. Now, if you will calculate the difference in the energy loss in the course of a year between conductors of 96 per cent. and 98 per cent. purity, it will be quite an item. There seems to be difficulties, however, in making exact tests for purity, and there is also a hesitancy on the part of laboratories in making reports as to whether the conductor is 97 per cent. or 98 per cent. pure. I would like to hear the experience of those who have made tests as to just what accuracy might be expected.

*Morgan Brooks*—M. W. S. E.—It is very difficult to say whether a wire is 97½ per cent. pure because of the impossibility of measuring wire diameters exactly. It was my business when with the American Bell Telephone Company a number of years ago, to make wire tests, and at that time there were no specifications for hard drawn copper that were recognized as efficient. I found it easy enough to determine the gauge of a wire in terms of B. & S. gauge numbers, but with the more accurate method, using the micrometer gauge, it is more difficult. The wire has some spring, and if not accurately straightened it is difficult to get the diameter right within 0.0001 of an inch.

When I was with the American Bell Telephone Company we used wires of moderate size. The largest was No. 6 or 8, as is used between New York and Chicago. The smallest was No. 12. An error of measurement of 2 per cent. of the diameter means an error of 4 per cent. in the area and weight.

A micrometer with a spring arrangement makes wire measurement much easier, as it equalizes the pressure each time. I found it convenient to measure off 100 feet of wire and weigh it. I found a specific gravity of 8.9 to be more nearly correct than 8.8, as ordinarily given.

I found the conductivity of certain wire tested at that time to be over 100 per cent. Fearing that to report it at that, I would lose my job, I simply said the wire came up to specifications; I do not yet know what the trouble was.

It should not be overlooked that in the larger sizes of wire, made up into cables, it takes about 1,020 feet of wire to make a conductor in 1,000 feet of cable. Another difficulty in figuring wire sizes, especially in lamp wiring, is that in the American gauge only even numbers of sizes are available in the market, and the differences between successive sizes thus available is about 60%. We introduce errors by choosing the nearest size to the calculated one.

# THE BIRTH AND GROWTH OF THE STEEL INDUSTRY IN AMERICA.*

JAMES N. HATCH, M. W. S. E.

The word steel has acquired such an important significance in the United States that the mere mention of the name brings at once to mind a score of mammoth things, none of which bear any resemblance to the definition of the word as found in the dictionary. Steel in the business world means stocks and bonds and corporations and prices. And steel in general has come to denote a commodity on which the present state of civilization depends more, probably, than on any other one thing that could be selected. We wonder how it was possible for our ancestors to make the progress they did when the products of iron and steel then was less in a decade than is now produced in a single day.

Nor is it necessary to go back to the time of our ancestors to see some wonderous strides; for within the past ten years the growth of the iron and steel industry has been so stupendous as to involve figures that are fairly bewildering. If the growth in the next ten years increases in the proportion that it has in the past ten years there is no human intellect that can conceive of the material progress that will have been attained at the end of that period.

Employed in the iron and steel industry there are over a million men. This means that perhaps 5 per cent. of the inhabitants of this country depend on this business for their living. The amount of capital invested runs up into figures that are incomprehensible, and the wealth of certain individual men, acquired in the iron and steel business, makes the fabulous wealth of the ancient kings only a mere pittance. If a person had been living at the time of Christ and had saved $100 per day every day since, putting it away in a bank without interest, the accumulation would be less than the reputed wealth of some individual steel magnates.

The growth of the iron and steel industry in the United States in the last fifty years has been without parallel in the industrial history of the world. Fifty years ago this country produced six hundred and fifty-seven thousand tons of iron and steel per annum, now it produces as much in a fortnight. In 1875 the entire production of the country was less than 2,000,000 tons, or less than is now consumed in wire products alone. In 1885 it had grown to 4,000,000 tons. In 1890 it had reached an annual production of 9,000,000 tons. From 1890 to 1897 the progress was slow, owing to the panic of 1893, but with the returning prosperity in 1898 there came a greatly increased output.

Roughly speaking, for the past half century the annual production of iron and steel has doubled every ten years. This means a rate of

*This paper was not presented before the Society, but is here printed because of its historical value.—PUB. COM.

growth averaging 10 per cent. per annum. Where this will stop no man can say, but that it must stop seems certain, as the supply of ore cannot hold out indefinitely under such an enormously increasing drain.

With the above figures in mind, giving some idea of the magnitude of the iron and steel industry as it is at present, it is interesting to look back along the pages of history and see where this mammoth creature had its birth, and to examine the environment in which the infant industry grappled for its early existence.

Iron and steel have been produced in America since its earliest settlement, so that the present great use of these products is more due to its present cheapness owing to improved methods of manufacture, than to the new uses to which it has been put. These new uses would have been prohibitive at the old prices. Attempts were made to manufacture iron in this country as early as 1619, but no permanent establishment was put into operation until about 1640. And it may really be said that during the entire seventeenth and eighteenth centuries the industry was so small, and of such an unstable nature, owing to arbitrary legislative restrictions and sharp foreign competition, that it can hardly be considered that the manufacture of iron was an established industry until the early part of the nineteenth century.

It is stated that the first successful attempt to manufacture iron in America was made in 1622 on the James River, Virginia, but that section never seems to have gained much prominence as an iron making center. Massachusetts seems to have the distinction of being the next state to begin the manufacture of iron, there having been a mill put in operation at Lynn in 1631, a blast furnace at Hammersmith in 1644, and a forge at Braintree in 1646. We find it recorded that Jenks cast pots at Raynham in 1646 and made saws in 1652. In 1702 the first charcoal furnace was built at Plymouth to reduce the lean bog ores found near by. These ores contained about 25 per cent. of metallic iron. The iron thus made was cast into hollow ware for domestic uses.

Maryland also figured as an iron producing state in the early part of the eighteenth century and a considerable amount of bar iron was made, beginning with a mill at Principio in 1717. This bar iron was suitable for making all sorts of small articles which did not require any tempering. It was in most part exported to the mother country. In 1724 Spotswood, Washington, and others built charcoal blast furnaces where pig iron was manufactured for export to England.

New Jersey also made some early attempts as an iron manufacturer as far back as 1765, when one Colonel Morris built a bloomery in Monmouth county, and began the production of refined iron.

In Pennsylvania, the first records we find mentioning the iron business are accounts of the forges built on the Schuylkill River by Hall, Nutt, and Rutter in 1717; shortly after this, 1726, Sir William

Keith built the first furnace in that state on the banks of the Christina River.

New York built her first iron works at Sterling in 1751. It was at these works that the great chain was made in 1778 to bar the Hudson River against navigation by the English war craft. This chain weighed 186 tons and was one of the most gigantic articles that had ever been constructed on American soil.

Thus it was that the iron business began its existence, and in a similar way it dragged along its half-starved life for nearly two centuries. As only a narrow strip along the Atlantic Coast was inhabited during these early times, whatever iron there was manufactured was of necessity produced in that region, using such natural resources as were found near at hand. The ore used was almost exclusively bog iron ore, which was found in abundance in the swamps and ponds near the coast.

The finished materials produced in America during the colonial times were in most part pig iron and bar iron. Pig iron is merchantable iron in its first stages of development, and is only suitable for castings. Bar iron is what is known as wrought iron and is a more refined condition than pig iron. These products were in most part shipped to England, where they were manufactured into the various commodities needed by the colonies. These commodities were then shipped back and sold to the original producers at a marked profit. The mother country, for lack of charcoal, could not economically manufacture large quantities of pig iron, and was therefore glad to procure this from the colonies, but she forbade the colonies manufacturing even their own ordinary agricultural and mechanical implements. So that, even though the colonies had been prepared and had so desired, they were not permitted to be home producers. They were compelled to look to the mother country for their supply of finished articles of iron and steel.

This state of affairs obtained throughout the early part of the eighteenth century and down to within a few years of the breaking out of the Revolutionary war. Not long after the relations between the colonies and Great Britain had begun to show unmistakable symptoms of an unfriendly nature, a number of moonshine iron mills were established. These turned out various finished products of iron and steel, clandestinely, in the fastness of the friendly forest, to supply the domestic needs of the settlers near by.

It is only natural, that having all these things to contend with, the growth of the iron indusry could not flourish luxuriantly, especially when at the settlers' very door there were no end of material resources waiting to be developed. There were unlimited agricultural advantages, which could be developed at an outlay of but a small amount of capital, and which brought early returns. Even hunting and trapping was the source of a fair income.

In spite of all these discouragements some progress had been made before the middle of the eighteenth century, and although the

amounts of manufactured articles were not large, considerable advancement had been made in the art of smelting and refining iron, and in the ability to fashion it into articles of commerce. The inventive genius of Yankeedom had already taken root, and a variety of small articles such as axes, hoes, sickles, shovels, nails, hardware, and some small machinery were manufactured. But in 1750 an effectual check was put on all progress in this direction by an act of Parliament which absolutely prohibited, as a common nuisance, the making of bar iron or steel by the American colonies.

So it is no surprise to learn, that, although the colonies exported nearly all the bar iron and pig iron which they manufactured, the total amount of these materials sent out from 1717 to 1770 was but 150,000 tons; an amount which the United States now manufactures each week.

With the breaking out of the Revolutionary War a new impetus was given to the manufacture of finished articles of iron and steel. A domestic market was at once created, and the breaking off of commercial relations with Great Britain removed the prohibitive restrictions and destroyed the unfair competitions, which had made the iron industry so uncertain before. A demand was at once created for such articles of domestic use as were required in ordinary agricultural and mechanical pursuits and for various implements of warfare. Cannon balls were cast in a number of early foundries, and such weapons as it was possible to fashion found ready sale. But during the time of the war and even afterward up until the close of the eighteenth century the iron industry was limited to implements for simple domestic, mechanical and agricultural purposes. There were no railroads, no steam engines of any kind, no steel buildings, or steel ships, no telegraph wires or wire fences, no steel bridges or steel cars. Pots and kettles, sadirons and clock weights, stoves and plow points were made at the furnaces. Very little steel was made and most of the finer grade of tools were imported. Nails were made in the chimney corners from rods which had been slit from bars in the slitting machine. It is related that Thomas Jefferson kept about a dozen of his younger slaves at work making nails, and that they made about a ton of nails per month, which were disposed of at considerable profit.

When the war was over and commerce was again established with Great Britain, competition in all branches of iron and steel products became so sharp that the growth of the industry in this country was again badly impeded. Especially was this true in respect to useful commodities and to a less extent in all kinds of castings. Steel was hardly manufactured at all in America owing to British competition. In fact, foreign competition was a serious obstacle to the growth of the iron industry in the United States during the entire first half of the nineteenth century. During fitful periods of relief resulting from the second war with Great Britain in 1812, and later from the tariff acts of 1824, 1828 and 1842, the

industry made some progress, but not until the tariff act of 1861, and the Civil War which began in that year, did the present steady forward movement begin, which has since made this country the greatest iron producing country in the world and has placed its civilization above that of any other country. The following table exhibits the growth of the iron trade since 1810. As the total iron and steel industry can be measured by the pig iron output from which all other products are made, the amount of pig iron in tons as manufactured each year since 1810 is shown in this table. Prior to 1810 there were no census reports and therefore no reliable record.

| | | | | | |
|---|---|---|---|---|---|
| 1810.... | 53,908 | 1867.... | 1,305,023 | 1885.... | 4,044,526 |
| 1820.... | 20,000 | 1868.... | 1,431,250 | 1886.... | 5,683,329 |
| 1830.... | 165,000 | 1869.... | 1,711,289 | 1887.... | 6,417,148 |
| 1840.... | 286,903 | 1870.... | 1,665,179 | 1888.... | 6,489,738 |
| 1850.... | 563,755 | 1871.... | 1,706,793 | 1889.... | 7,603,642 |
| 1854.... | 657,337 | 1872.... | 2,548,713 | 1890.... | 9,202,703 |
| 1855.... | 700,159 | 1873.... | 2,560,963 | 1891.... | 8,279,870 |
| 1856.... | 788,515 | 1874.... | 2,401,262 | 1892.... | 9,157,000 |
| 1857.... | 712,640 | 1875.... | 2,023,733 | 1893.... | 7,124,502 |
| 1858.... | 629,548 | 1876.... | 1,868,961 | 1894.... | 6,657,388 |
| 1859.... | 750,560 | 1877.... | 2,066,594 | 1895.... | 9,446,308 |
| 1860.... | 821,223 | 1878.... | 2,301,215 | 1896.... | 8,623,127 |
| 1861.... | 653,164 | 1879.... | 2,741,853 | 1897.... | 9,652,680 |
| 1862.... | 703,270 | 1880.... | 3,835,191 | 1898.... | 11,773,934 |
| 1863.... | 846,075 | 1881.... | 4,144,254 | 1899.... | 13,620,703 |
| 1864.... | 1,014,282 | 1882.... | 4,623,323 | 1900.... | 13,789,242 |
| 1865.... | 831,770 | 1883.... | 4,595,510 | 1901.... | 15,878,354 |
| 1866.... | 1,205,663 | 1884.... | 4,097,868 | 1902.... | 17,821,307 |

With the beginning of the nineteenth century the present steady growth of the iron industry in the United States commenced. It was then that the tide of civilization began to flow steadily westward, and as civilization was not possible without iron and steel, it was imperative that these commodities should keep well in the forefront of this movement. There was only one way that this could be accomplished and that was by the building up of iron manufacturing establishments on the frontier as civilization advanced. To have attempted to ship machinery or other heavy articles of iron, far inland, would have been an impracticable undertaking. The transportation of such articles, if possible at all, was so expensive as to be prohibitive. As an example, in 1789 the crank for the first saw mill in Ohio was carried by pack horses over the Allegheny Mountains down to the Youghiogheny River and there shipped by water to Marietta, Ohio. This crank weighed 180 pounds and was made at New Haven, Conn., for the New England Ohio Co. The transportation of this piece of machinery probably cost not less than one dollar per pound.

Very naturally, under such conditions, no sooner had the early

settlers pitched their tents on a new spot in the wilderness than they began looking about among the natural resources near at hand, for the proper materials with which to construct such commodities as their immediate necessities demanded. These searches were rewarded, not only by finding iron ore of as good quality as they had been using along the Atlantic Coast, but the Pennsylvania ores were soon seen to be much superior to anything that had been found further east. With this high-grade ore in abundance, an exhaustless water supply to furnish power, and a boundless forest from which to make charcoal, the inland iron industry soon began to be on a firm footing. There was another great advantage which these inland manufacturers possessed, a freedom from competition. Along the sea coast the foreign products could be laid down at a price that could not be met by the early American manufacturers, but the mills of western Pennsylvania and Ohio were in a large degree free from this competition owing to the prohibitive rates of inland transportation. Points along the Ohio River were very favorable to distribution west and south and points in Ohio for distribution west and north. So that vicinity as long as it was protected from foreign competition carried on a flourishing industry.

From the above tables it will be seen that commencing with the year 1830 the consumption of iron began to be an important item in the commerce of this country. Railroad building, which started at that time, created a very large demand for iron. Not only was this true on account of the iron which was actually consumed by the railroads themselves, but their introduction brought about a tremendous and rapid development in the West which created a new demand for all kinds of agricultural and mechanical implements, building materials, and household commodities. From the tables it will be seen that this growth was steady from 1830 to 1856; after that there was no real growth until the beginning of the year 1862, when the tariff act gave the home trade better protection. During the six years mentioned, the population increased over four millions. And this increase in population of 23 per cent. would naturally presuppose a corresponding increase in iron consumption, so that the figures really show a decided retrogression in the American iron industry. This period of decline was largely due to foreign competition, which was again made possible, even in the West, by the greatly improved shipping facilities. The system of canals and railroads, supplemented by the lakes and rivers, made the distribution of foreign iron an easy matter.

With home protection assured, in 1862 the iron business was again on its feet and since that time the growth has been fairly uniform and has more than kept pace with the increase in population, for while our population has increased on an average of 24 per cent. each ten years since 1860, the increase in the iron output has been 100 per cent. in each ten years.

After the close of the Civil War business became active in all parts of the country. Railroads were built into the far West and

a wonderful development began, requiring immense quantities of iron and steel, and it was about this time that the steel business really began on a commercial basis. Iron mines were opened and furnaces were built all through the middle West and South.

Prior to 1855 most of the iron made in this country was made with charcoal. About this time it was found that a very good grade of iron could be made with anthracite coal instead of charcoal, and at a very much less cost. The Franklin Institute offered a gold metal in the year 1835 for the largest amount of iron made with anthracite coal in one year, by one firm, provided the amount exceeded twenty tons. Not long after this it was found that a very good iron could be made by using coke made from Pennsylvania bituminous coals. In 1869 the amount of iron made with bituminous coke exceeded for the first time the charcoal iron. At the present time the coke process is used almost to the exclusion of the charcoal process.

Before the extensive introduction of bituminous coal to replace charcoal the iron furnaces were built near the iron mines, and the iron was shipped out in the shape of pig iron. But when the Pennsylvania coals began to replace charcoal the great mills began to grow up near the coal fields. Pittsburg thus got an early start in this direction, partly because it was adjacent to good ore mines and coal fields and partly because it was at the head of navigation on the Ohio River, which was the great highway over which the early settlers of the West received their merchandise.

It is interesting to note the numerous things which happened in the year 1855 to help revolutionize the iron and steel business; the locks at Sault Ste. Marie were completed in that year and in consequence the great ore shipping business from the Superior region began; in that year charcoal was supplanted by mine coals in more than half the iron made, and in the same year Bessemer introduced his converter for making steel.

The introduction of the Bessemer process of making steel was a wonderful advancement and it was not long after its introduction till steel could be manufactured cheaper than iron. Another coincidence was that the Superior ores being exceptionally pure were especially well adapted to this process of manufacture.

The manufacture of iron has been, and, in fact, still is, a slow-going process. There has never been devised any machine that could replace the puddler, and there was very little chance for a great revolution in the manufacture of iron, but as soon as a mechanical process was devised for making steel the business was a prosperous one. In almost every branch of structural work, and especially with railroad rails, the change from iron to steel was made almost immediately. This was not only because steel had become cheaper, but also because it was far superior.

The iron manufacturers in and around Pittsburg seemed to see with almost prophetic vision, in the change from iron to steel, the opening of a new era in the business world. The great reductions

in cost which were possible by the use of labor saving machinery had already been demonstrated to these iron manufacturers, and as they were satisfied that this new mechanical process of making steel was a success, they seemed to realize in a measure the tremendous possibilities of the business. Pittsburg has always been, and still is, the center of activity in this great business. It is hardly likely that this center will move far away from Pittsburg unless some new process be discovered of extracting the iron from its ores, or of making suitable coke from the western coals.

In this brief resume something has been seen of the rise and growth of a business which is now second to none in the world, not only in magnitude, but in importance to civilization. The business as we see it to-day is stupendous, incomprehensible; what it will be in another fifty years we will let time tell.

BERLIN (NW. 7), end of June, 1906
Dorotheenstr. 49.

**The Technolexicon of the Society of German Engineers** (short report on the state of work in June, 1906, and on the **beginning of printing**). About 2000 firms and individual collaborators at home and abroad are assisting in the compilation of this *universal technical dictionary* for translation purposes (in the three languages English, German, and French), that was commenced in 1901. Over 3000000 word-cards have been collected. Alphabetizing has so far advanced that printing will begin early in 1907.

**The work will be printed and published by the well-known firm of J. J. Weber, Illustrierte Zeitung, in Leipzig.**

The undersigned will be pleased to give any further information wanted; address: Technolexicon, Berlin (NW. 7), Dorotheenstrasse 49.

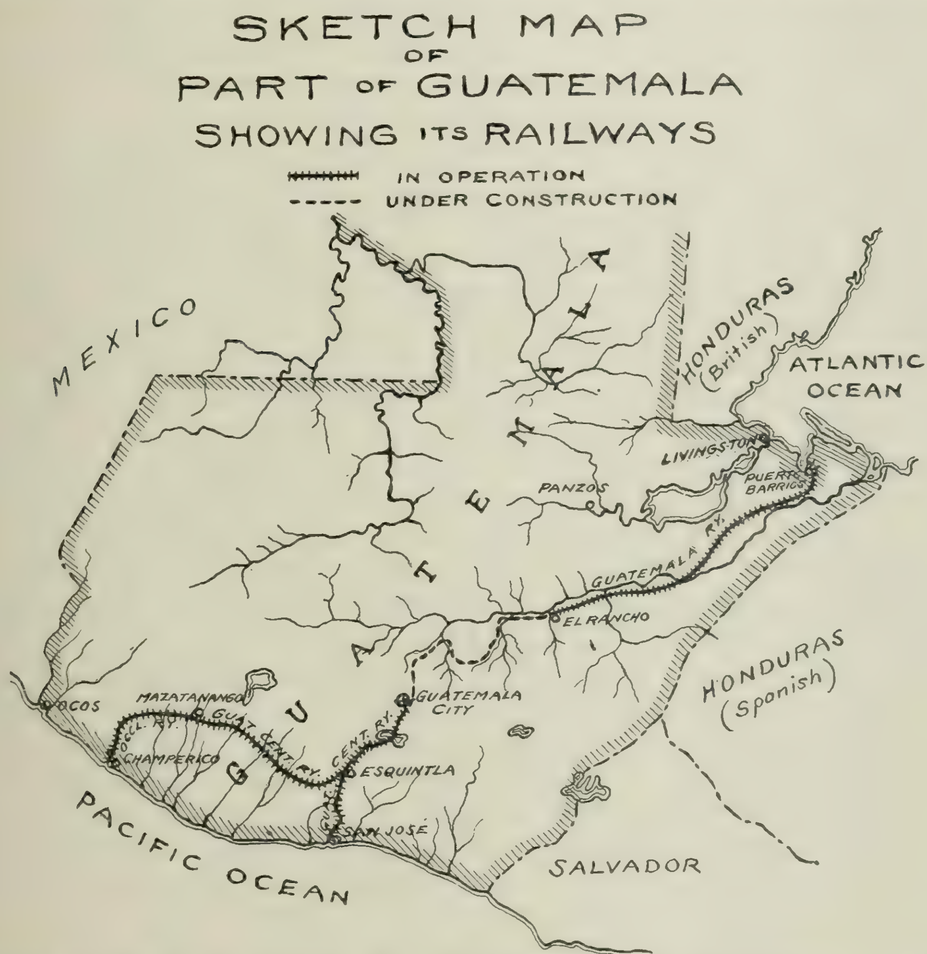
THE EDITOR-IN-CHIEF:

Dr. Hubert Jansen.

# THE GUATEMALA RAILWAY.

John Y. Bayliss, M. W. S. E.

More than 20 years ago a concession was obtained to build a railway across the Republic of Guatemala from the Atlantic to the Pacific. As is common in the Latin American countries, the project has suffered many reverses. More than once the work of advance construction has been entirely abandoned for several years at a time. About three years ago a new company secured the concession to complete the road. This company brought the capital and the new




blood necessary to revive the rapidly decaying enterprise. Under the name of the Guatemala Railway, the connecting link between the two oceans is now assured. This railway is to cover the distance from Puerto Barrios on the Atlantic to Guatemala City, the capital of the republic, 195 miles in all. From Puerto Barrios to El Rancho, 135 miles, is now in operation, the remaining 60 miles, under construction, being in broken, mountainous country, and constituting the heaviest part of the work. The ascent to Guatemala City from

San Jose on the Pacific, a distance of 75 miles, was a much easier undertaking. The Central Railway of Guatemala has been running freight and passenger trains on a daily schedule between these two places for a number of years. These two railways, then, when the Guatemala Railway is completed, will form together the trans-continental line. At the time the inter-oceanic railway was first conceived it was evidently expected to divert some of the through traffic from the Panama railroad. No such hope is entertained for it now; whatever of international significance it may have had 20 years ago has been lost in the latter-day developments of railroad perfection. There are in Central America two other coast-to-coast railways, one in Costa Rica from Port Limon to Punta Arenas, and the other in Mexico from Coatzacoalcos to Salina Cruz. Only the latter can be said to approach in any degree to the requirements of a trunk line.

When the present company took over the Guatemala Railway, then known as the Guatemala Northern, the track extended from Puerto Barrios to El Rancho, all of which was in a deplorable state of delapidation. This portion is largely in the bottom lands, passing through salt marshes and tropical undergrowth and thence following up the Rio Motagua, the largest water-course on the Atlantic side of Guatemala. By this river route it emerges from the thickly vegetated country, keeping close to the edge of the river for most of the distance, passes through a hot, arid, sandy belt and finally reaches El Rancho, about 900 ft. above sea-level. From El Rancho, the last point on the Motagua River, the heavy mountain grades begin. This is the portion on which new track is now being laid.

A general reconstruction of the old line from Puerto Barrios to El Rancho has been, and still is, a most important item of the undertaking. Many delays have been encountered here, so that, although more than two years have elapsed since this was begun, the railway is still in a very unsatisfactory condition. Annual freshets in the Motagua have carried away roadbed and bridges almost as fast as they could be rebuilt. A three-span Pratt truss bridge, resting on steel concrete-filled cylinders over the Motagua River was washed out and has been replaced. The same form of construction was used in the new structure. New cylinders were driven deeper into the clay and hardpan of the river bottom and two of the spans were replaced by new steel work. The bridges across the many water courses tributary to the Motagua were for the most part unsafe as to foundations. They were largely through truss bridges of single span, varying in length from 100 to 200 ft. In many cases the foundations were rebuilt entirely and the old bridges replaced on the new abutments. This work is not yet entirely completed. New ties and ballast were needed over the entire line, the old ties to be replaced by creosoted yellow pine ties from the United States. Good ballast is available in most localities, river gravel being largely used. This is distributed on flat cars, which are loaded and unloaded by hand. The old rail of English make, 54 lbs., is still in excellent

condition and needs no renewal. The delivery of ties has been slow and the labor very uncertain, which accounts in some measure for very slow progress made in this direction.

The gauge of the old track was 3 ft. and this has not been changed in any of the new work. The new bridges and tunnels, however, are designed for standard gauge to facilitate a transformation at some later time should it be desired. The work of grading the line ahead has been carried on simultaneously with the reconstruction, but no new track was laid until January of this year. The line from El Rancho is for the most part on the side hill The general topography of the country is such that reverse grades have been difficult to avoid. There are three summit levels between El Rancho and Guatemala City. The highest of these summits reaches an elevation of about 5,000 ft. above sea-level and affords an excellent view of the city of Guatemala, spreading out in a fine broad valley a few hundred feet below. The roadbed, of course, is for single track, although suitable places for ample sidings have been found and utilized throughout the mountain division. The width of roadbed is 16 ft. for cuts and 12 ft. for fills. The material encountered various greatly and is almost wholly the result of volcanic deposit. Limestone is found frequently in boulders, rarely in ledges. The volcanic material ranges from soft, volcanic pumice called "talpetate" to the hardest obsidian. The former can be cut easily with a shovel, while the latter is extremely unyielding, both to drills and explosives. The limiting conditions adopted in the location of the route are 19° curves and 3 per cent. grades, compensated for curvature at the rate of 0.04 per cent. for each degree. Grading is done by contract, using native Indian labor drafted by the government. The rate of pay for ordinary labor is 3 pesos (24 cts. gold) per day. The work is paid for by the yard, at a stipulated price for both excavation and embankment, the excavation being classified and the contractor being required to haul from cut to fill within the limit of 500 ft. Above 500 ft. he is allowed to borrow material at the contract price for excavation, which may or may not be classified according to the discretion of the chief engineer. Three tunnels will be built, the longest probably not exceeding 500 ft. The grading has nearly reached completion, except with respect to the tunnels.

In the 60 miles from El Rancho to Guatemala City there are about 55 steel bridges in various stages of completion. Ten of these bridges are viaducts, the largest being 743 ft. long, with a maximum height of 229 ft. One viaduct, 225 ft. long, maximum height 33 ft., which has already been erected, was built on an 18° curve and a grade of 2.28 per cent. The steel work is furnished by the Baltimore Bridge Co., and is erected by contract, the railway company furnishing the contractor with a locomotive and train crew, a heavy derrick car and a complete equipment for pneumatic rivetting. The hillside country is very broken, all the mountain slopes being cut by sharp ravines called "quebradas." These are frequently very

deep and in the rainy season they discharge large quantities of water in a short space of time. Whenever practicable these water courses have been provided for by culverts, most of them arched and ranging from 3 ft. to 25 ft. in diameter. The smaller culverts and some of the abutments for smaller bridges have been built of good ranged rubbele with native lime mortar. This native lime will bear mentioning. It is burned by the natives in native-made kilns, the stone used being dark blue limestone found in small boulders. Unlike our lime in the United States it is not much injured by air slaking. Native masons make no effort to protect it from ordinary weather and will sometimes get rather remarkable results from lime that has been reduced by air and sun to a fine powder. It has been used to some advantage on the Guatemala Railway, although the practice is not thought to be above question. In this case the difficulty of transporting cement on mule back is largely responsible for the use of lime, which can be burned almost on the site of the work.

On the mountain division 60 lb. rails from the Carnegie mills are used, with 14 ties (creosoted yellow pine) to the rail length of 30 ft. A very good grade of ballast is gotten from the cuts, 6 inches of ballast being required under the ties. As on the reconstruction work, the ballast is hand-loaded and distributed by work train. The track-laying is also done by hand. Rails are curved with an ordinary roller rail curver for all curves of 6° and over.

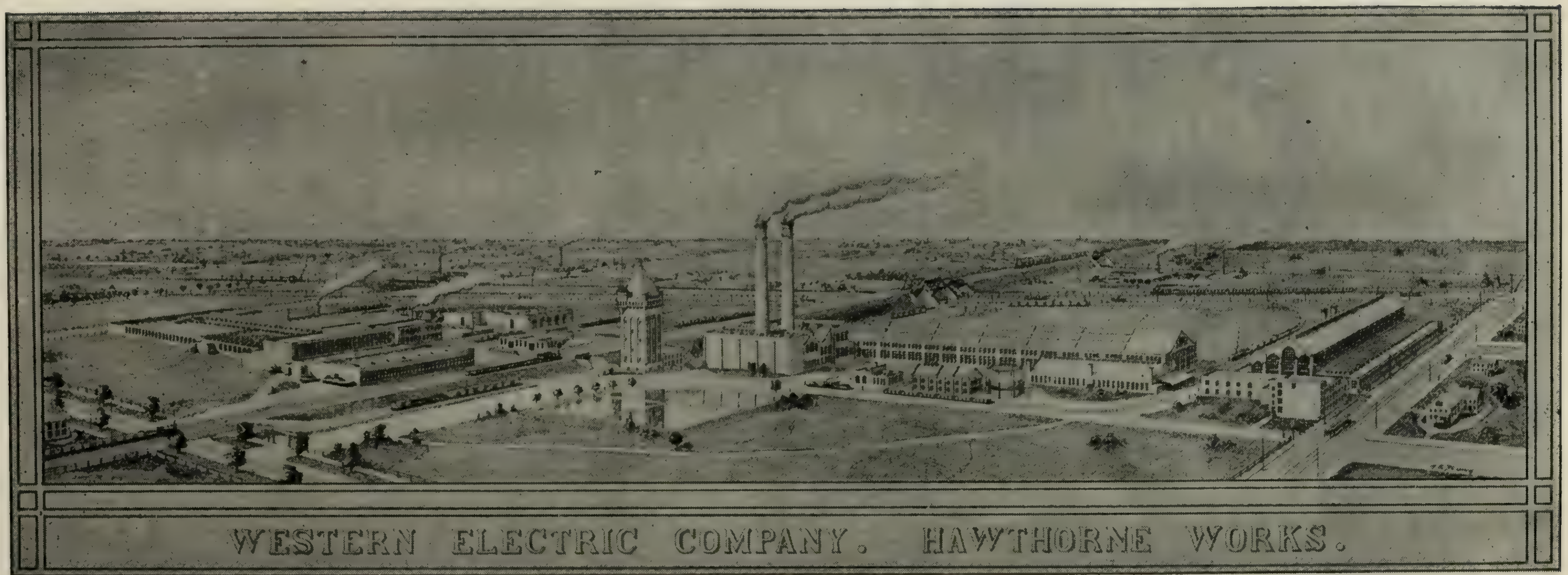
The rolling stock for the railway is all American make. Baldwin engines are used, equipped with the New York air brake. The heaviest type of locomotive is about 75 tons.

The natural features of Guatemala, as far as they relate to the railways, are partly matters of prophecy, for the republic is yet undeveloped. The products of the country are largely agricultural. The interior of Guatemala is wholly mountainous, the average elevation being above 5,000 ft. Like most mountainous countries in the tropical belt, it has a variety of climates, ranging from the ultra-tropical along the coasts to a temperate in the mountains. The bottom lands are sickly, but the high interior can boast a climate that is unsurpassed for healthfulness. The wet season lasts from April to about October, but the rainfall is much more moderate in the mountains than is usual in tropical latitudes during the rainy season. As far as is known, there are few minerals of value in Guatemala. Mica is mined on a small scale and silver was found in paying quantities during the early history, but at present there are no mines of any consequence in operation. The main commercial products are bananas, sugar and cocoa in the low country, and coffee and live stock in the middle altitudes. The bananas for export are raised on the east coast and are handled principally by the United Fruit Co. The west slope of the mountains, however, is much the richer. It is there that the coffee crop of the country is most abundant. Coffee of superior quality is raised in Guatemala and is the largest export. Fine pampas covered with a giant grass are also

extensive along the western slopes, and the indications are that cattle will be raised there to good advantage when the new railroad can offer a better outlet to the market. The population of the whole republic is about 1,300,000, of which the capital, Guatemala City, contains 70,000.

At present there are some 375 miles of railways in operation in Guatemala. The Guatemala Central embraces the line from Guatemala City to San Jose and from Esquintla to Mazatamango, in all 145 miles. The Occidental Railway has 42 miles between Mazatanango and Champerico. The Guatemala Railway, as stated before, operates at the present time 135 miles from Puerto Barrios to El Rancho. There is also a railway running about 25 miles inland from Ocos on the Pacific, and another 28 miles in length from Panzos, which has steamer connection with Livingston. The latter two railways are not shown on the accompanying sketch map. It is also proposed to extend the Guatemala Central north to connect with the Mexican lines and the Guatemala Railway south to Salvador.

The engineering work for the Guatemala Railway is under the direction of Mr. S. F. Shaw, Chief Engineer, Mem. Am. Soc. C. E.




General View.

## THE HAWTHORNE SHOPS OF THE WESTERN ELECTRIC CO.

H. R. KING, M. W. S. E.

*Presented before the Electrical Section, May 18, 1906.*

The Hawthorne shops of the Western Electric Company consist of six principal groups of buildings. The office, the foundry, forge shops and machine shops, devoted to the manufacture of direct and alternating current motors and generators, are located on the west side of Belt Railway. The cable and rubber plants, devoted to the manufacture of telephone and power cables, and rubber in the various forms in which it is used for telephone service, are located on the east side of the railway.

In addition to these buildings there is a gas plant, water tower, power plant and two crematory buildings. The entire plant covers approximately 1,000,000 sq. ft. of floor space and is located on a tract of land of 110 acres. The Chicago Terminal and Manufacturers' Junction Railway tracks pass through the property and connection is made by an elevated spur track to the main line of the Chicago, Burlington & Quincy Railway.

The grounds are artistically laid out and the drive-ways connecting all the buildings are paved with concrete block.

### BUILDINGS.

Foundry.

The foundry is a brick and steel structure, 400 by 176 ft. in plan, and is 75 ft. to its highest point, with a Ludewici tile roof. It is divided into three bays; over the center, or main bay, which is for large work, are two 30-ton traveling cranes. The west bay is 75 ft.

wide and has a low roof, it being used exclusively for bench work. The east bay, which is 30 ft. wide, is divided into sections containing the cupolas, storage bins and core ovens.

The machine shop, lying at right angles to the foundry, is 860 ft. long and 150 ft. wide, and is of the same general type of construction as the foundry, except the roof, which is of iron construction, with tarred roof. There are three bays; the center one, 76 ft. wide, is devoted to the manufacture of generators and motors. The north bay, 48 ft. wide, contains such machine tools as are required in the manufacture of small types of machines. In this bay is located the testing department. The south bay has two floors, the upper one being devoted to the manufacture of small field coils and the winding of small armatures. It also contains the small detail and

Machine Shop.

finishing departments. The lower floor contains the commutator and large detail departments, stock rooms and general shop offices, including that of the shipping department. The lighting is obtained from overhead skylights and side windows. Over the main bay are located two 30 ton, and over the north bay, six 20 ton cranes. The entire plant is equipped with a system of industrial railways.

### CABLE PLANT.

Entering the cable plant from the south is a railway track connecting the receiving department, which covers 15,000 sq. ft., at which the raw material is received. Adjacent to this are the insulating and wire twisting departments, covering 22,500 sq. ft., and from which the material passes into the cable twisting room, covering the same area. From here the cable passes into ovens, covering an area of 10,000 sq. ft. finally delivered through small openings in the wall to the press room, where the lead sheath is applied. This room is 360 by 100 ft. At the south end is located a storage pit for lead, in which, under normal conditions, is stored 4,000,000 lbs.

Immediately adjoining this section, is a room 100 by 50 ft. in which is a battery of six impregnating tanks, used in the insulating

of power cables made in another adjoining room, of 15,000 sq. ft. area. In addition to these departments, there are the testing and shipping sections, covering an area 440 by 50 ft.

There are other buildings in process of construction, and almost completed, which will increase the capacity of the present plant over 100 per cent.

The rubber plant forms an L to the cable plant, and is located immediately south, with an open space or court 200 ft. sq. dividing it from the cable plant; this is used for the storage of cable reels. It has the same railroad connection as the cable plant, and is divided into four sections, the compound-mixing, grinding and vulcanizing, sawing and finishing and shipping rooms, all covering an area of 40,000 sq. ft.

Interior of Machine Shop.

A portion of this plant is two stories high, the second floor being devoted to the process of drying crude rubber. The buildings of the cable and rubber plants are identical in that they are of brick and steel construction—a special feature being a saw-tooth roof construction, so built that the windows face the north. This type of roof is used entirely in this section of the plant, except in the press-room of the cable shops (where crane service is furnished by one 20 ton and one 5 ton crane), and in that portion of the rubber plant having two stories.

POWER PLANT.

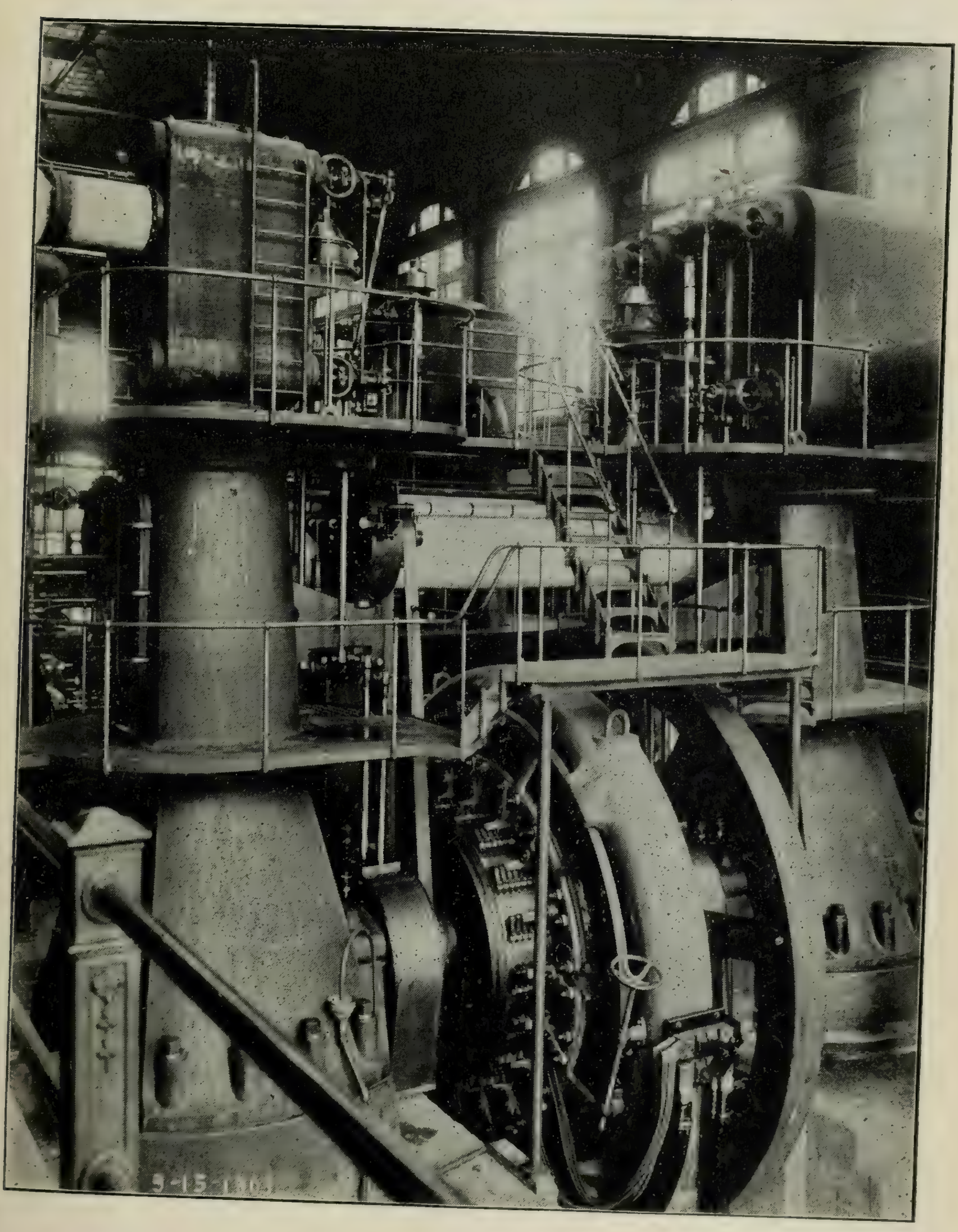
The boiler room has an area of 20,700 sq. ft. and is designed for two chimneys, each 12 ft. inside and 22 ft. outside diameter, and 250 ft. in height above the boiler room floor. One of these chimneys has been built and the other is in process of construction. Provision has been made for two batteries of boilers of eight each, a chimney dividing each battery into two sets of four boilers. At present there has been installed eight boilers of Aultman & Taylor Co's make, each with a heating surface of 5,080 sq. ft. and working at 150 lbs. Contracts have been made for increasing the boiler capacity 25%. The present boilers are so arranged that superheaters may be installed at a later date, should it be thought advisable.

The Aultman & Taylor Co's chain grate stokers are used having a grate area of 77 sq. ft. Each set of four boilers is provided with a Greene fuel economizer of 68 sections, 12 tubes wide. The water-tubes of the boilers are cleaned by means of a hydraulic driven cleaner supplied with water from a 7½ by 5 by 6 ins. Deane duplex pump.

The main railroad tracks dividing the company's property afford an easy means of handling the coal, as they are of such a height that cars may be switched by means of an elevated spur track to the storage bins located above the boiler room. These bins are of 1,000 tons capacity and are so designed that the coal may be discharged through spouts into a hopper scale for each division of boilers. This scale is mounted on a track, so as to take the coal from any part of the bin and deliver it to any one of the stokers. The ash is discharged at the end of the chain grate stoker into a bin of 1½ tons capacity located below each boiler. From these bins the ash may be delivered into gondola cars and taken by means of a depressed railroad track to various places about the plant where filling may be required.

The continued uncertainty of the coal supply, due to strikes and other conditions beyond the control of the manufacturer, has led to a careful consideration of the problem of coal storage. The Western Electric Co., after carefully investigating the question, decided to follow the practice adopted by the British Admiralty. Two storage bins, one of 4,000 and the other of 10,0000 tons capacity, both located below the normal ground level, have been constructed, into which coal may be dumped from cars and taken out by means of a locomotive crane fitted with a grab bucket. Carefully executed tests in Europe show that nearly 30% of the heating value of coal is lost in six weeks when stored exposed to the air. By keeping the bins flooded the company expects to reduce the losses of the coal to approximately 2% of its heating value after six months to a year storage. By this system of storage there is provided sufficient coal to operate the plant under normal winter conditions for four months.

A Cochrane open feed water heater of 8,000 H. P. capacity and two 14 by 10 by 15 ins. Worthington duplex vertical type boiler feed pumps are located in the boiler room.



Part of Power Plant.

The engine room and condenser pit have a total floor space of nearly 16,000 sq. ft. contain a power plant of a capacity for continuous service of 3,000 K. W. and for two hour service of 4,500 K. W. There are four units, one each of 300, 500, 1,000 and 1,200 K. W. capacities.

The larger generator is driven by a vertical cross-compound Rice & Sargent engine made by the Providence Engine Works. The diameters of the cylinders are 32 in. and 62 in., the stroke 48 in. the piston speed is 800 ft. per minute; the 300 and 500 K. W. generators are driven by a horizontal cross-compound engine, and the 1,000 K. W. by a vertical cross-compound made by the Filer & Stowell Company. The cylinder diameters, stroke, and revolutions per minute, are as follows:

300 K. W.—engine, 16 in. by 32 in. cylinders, at 100 R. P. M.
500 K. W.—engine, 20 in. by 40 in. cylinders, at 100 R. P. M.
1000 K. W.—engine, 30 in. by 60 in. cylinders, at 80 R. P. M.

Three Wheeler surface condensers are located in the condenser pit, two of 3,200 sq. ft. and one of 4,500 sq. ft. cooling surface; also three Blake duplex single-acting air-pumps, 7½ in. by 16 in. by 10 in. units for the smaller condenser and 9 in. by 20 in. by 12 in. units for the larger condenser. The condenser water is obtained from a reservoir of 5,000,000 gallons capacity which is primarily for fire protection purposes. Two fire pumps of 1,500-gallon-per-minute capacity get their supply from this reservoir.

Two 10 in. and one 12 in. motor driven centrifugal pumps are used for circulating the water and operate under a load of 37 and 45 H. P. respectively. These pumps are called upon to furnish only sufficient power to overcome the friction of the pipes, as the condensers are located below the level of the water in the reservoir, the suction and discharge pipes being submerged.

A 20 ton crane with a 5 ton auxiliary hoist is located over the engines, and a 15 ton crane over the condenser pit.

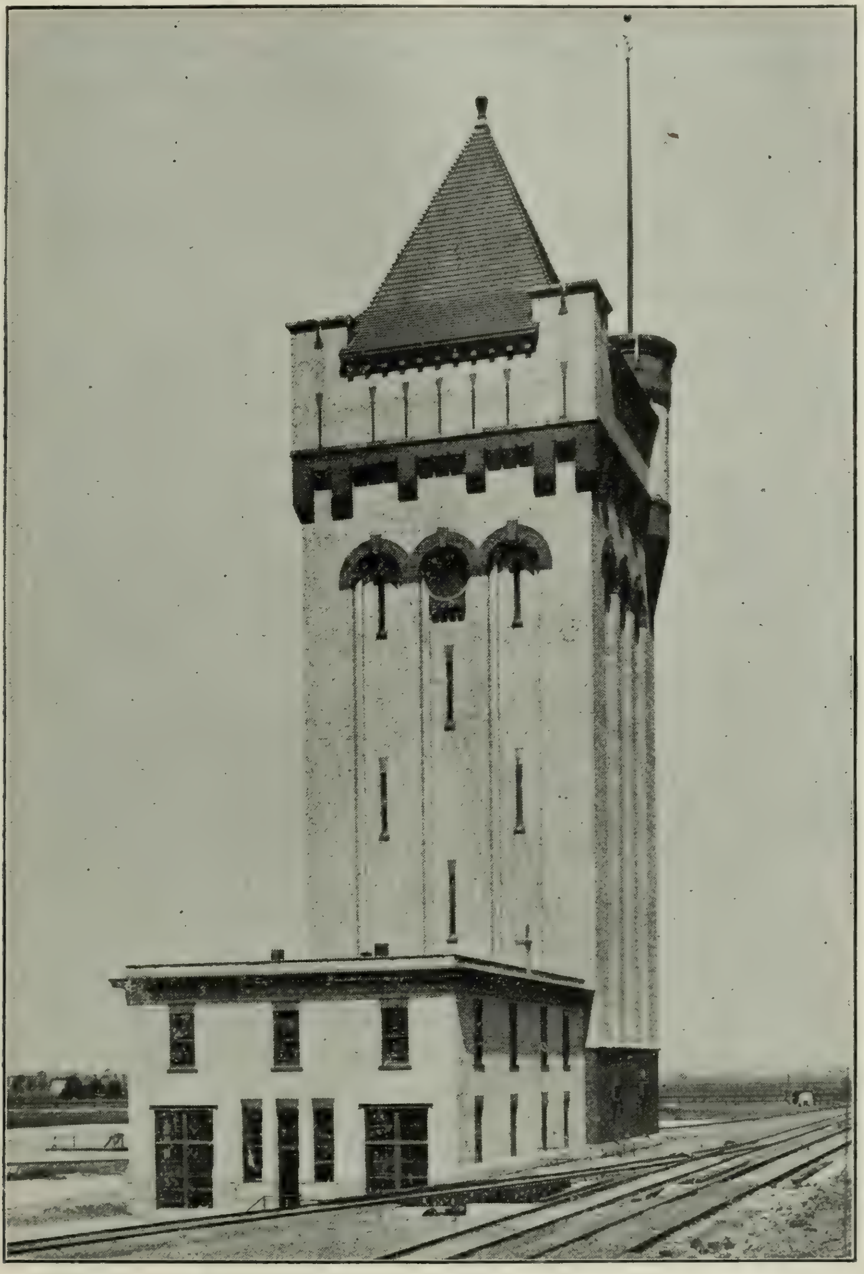
## ACCESSORIES.

In addition to the reservoir previously referred to, a water-tower of artistic design has been provided in which are located six steel tanks with a total capacity of 213,000 gallons, connected with the sprinkler system, the bottom of the lowest tank being 38 ft. above the highest sprinkler in the plant. Means are also provided for connecting these tanks with the hydrants throughout the plant. The water-tower also has tanks containing water for sanitary purposes. City water is used in both the reservoir and the tower.

Drinking water is obtained from a well, 300 ft. deep, at the rate of 40 gallons per minute by a direct acting deep well pump, and is piped to all departments. The water has a temperature of about 56 degrees Fah.

Compressed air is used for the purposes of pneumatic tools, blowing out cables and electric machinery, and operating moulding machines. The entire plant is supplied with air at 90 lbs. pressure by a 20 by 12 by 18 in. Laidlaw-Dunn-Gordan two-stage air compressor direct driven by a 12 by 19 by 18 in. compound engine, fitted with a Meyer release gear.

Uncarburetted water gas, used in the heating and baking ovens and annealing furnaces about the plant, is furnished by two generators, each with a capacity of 25,000 cu. ft. per hour.



Water Tower.

The gas is stored in a tank of 100,000 cu. ft. capacity, and has a heating value of approximately 300 B. T. U. It is made from a good grade of furnace coke, and costs, exclusive of fixed charges, such an amount as to compete favorably with 12,000 B. T. U. coal at $2.80 per ton. It has approximately 50% of the heating value of, and costs 50% less than city gas.

There is now being constructed a gas tank of 200,000 cu. ft. capacity, the use of which will enable the company to run one gas generator during the entire twenty-four hours, with pronounced economy over present conditions, which require both generators to work at certain times of the day.

All buildings are heated by direct radiation except the foundry and machine shops, the foundry being equipped with a hot air system furnished by the New York Blower Company, while the machine shop has a combined direct radiation and hot air system using the apparatus of the Garden City Fan Co. The heating coils are supplied with steam under the Warren-Webster system. Two 8 in. by 14 in. by 16 in. Blake simplex vaccuum pumps are used in connection with the system.

In the winter time one or more engines are operated non-condensing, the steam circulating under slightly less than atmospheric pressure. The efficiency of the above arrangement is apparent when it is considered that during last winter no steam was required for heating other than that furnished by the exhaust of the engine.

The crematory, having an area of approximately 1,600 sq. ft. cares for the shavings and chips from the carpenter shops. It contains a boiler and Dutch oven specially designed for the purpose. Provision for 100% increase in capacity has been made. The carpenter shops are equipped with an exhaust system from the various machines, and are provided with an edging "hog" which grinds the larger scrap lumber into shavings small enough to pass through the exhaust pipes into the crematory boiler, which is directly connected to the main steam line. Under normal conditions there is evaporated about 400 gallons of water per day to steam at the pressure of 160 lbs. per sq. in. thus augmenting the steam supply.

## FIRE PROTECTION.

Realizing fully the serious results to the business of the company of temporiarily crippling even one of the departments of the plant, careful consideration has been given to the fire hazard; neither money nor thought has been spared to reduce this hazard to a minimum and to provide means to quickly control any blaze that might break out. The result has been that the company is saving yearly, large sums of money in its insurance cost, and they now feel that as a result of the money expended, there has been produced a manufacturing plant in which the fire hazard has been reduced to a minimum.

An engineer trained in the inspection of manufacturing properties, devotes his entire time to the fire protection devices and to the safe-guarding of all of the processes of manufacture. In general, the different departments have one story buildings by themselves, each far enough removed from its neighbor to eliminate the danger of fire spreading. Large areas are divided by heavy fire walls with double tin-clad fire doors at the openings.

The walls are of brick, with wire-glass windows at exposed points, and the floors of concrete or concrete with wooden surface. The roofs are tile on structural steel.

With the exception of three buildings, the property is protected throughout by automatic sprinklers. The three exceptions are the foundry, forge shop and main body of the machine shop, in which there is absolutely no combustible material.

An interesting feature is a circle of sprinkler pipes with heads on the side of each steel post supporting the roof in the machine shop. These heads are about 15 ft. above the floor and are designed to protect these posts from danger that may arise from inflammable material gathering about their bases. The sprinkler system is supplied with water through an elaborate yard system of about 13,000 ft. of 10 in. and 12 in. water pipe, the feed into each building being controlled by a gate with a post indicator so that the supply may be regulated without entering the building, a valuable feature in time of fire.

Forty fire-hydrants, each with three or four independent gates, are located about the property on the same yard mains that supply the sprinkler system and are so placed as to make possible the complete surrounding of any one building by fire streams. Each hydrant is protected by a wooden house in which are stored hose play pipes, axes, lanterns, etc. The amount of hose varies per hydrant from 200 ft. to 500 ft., depending upon the length of the line that the particular hydrant is likely to be called upon to furnish. There is also 1,000 ft. of hose on the carts in the fire station. This makes a total of about 6,000 ft. of 2½ in. fire hose.

In the fire house adjoining the tower containing the sprinkler tanks, are two 1,500 gallon Underwriters' fire pumps ready for instant duty. These pumps are each capable of throwing six good fire streams and draw their supply from the large reservoir mentioned above, pumping into the yard system, thus supplying both the sprinklers and the hydrants as needed.

There is available in the tower for the sprinkler system and hydrants, 213,000 gallons of water, and as soon as the pumps are placed in operation an additional supply of 3,000 gallons per minute is available so long as the 5,000,000 gallon reservoir holds out. Running both pumps full capacity, the reservoir will last for 27 hours.

All of the buildings are liberally equipped with water and sand pails for fire use, with chemical extinguishers and with small hose connected to the sprinkler system. There is about 4,500 ft. of this small hose distributed throughout the different buildings.

This elaborate and expensive system of fire protection would be of small value if trained men were not available for instant fire duty; therefore the company maintains a fire brigade among its employes.

An ex-member of the protective department from the city of Chicago, is the chief of the fire department, and devotes his time

solely to the apparatus and the training of the brigade. Under him during the day, are sixteen men employed in the departments near the fire house who respond to all alarms. These men are picked for this special duty and are given extra compensation, including pay for drills as well as for fire service. At least twice a week a trial alarm is rung in, the department drilled with the use of the different apparatus, and familiarized with the surroundings and conditions that they would be likely to meet in time of fire. At night nine watchmen with a fire captain form a brigade; there being at least five of them at all hours of the night in the pump house where beds are provided for sleeping accommodations.

A system of forty-seven fire boxes are being installed, permitting prompt notification to the fire house, the members of the fire brigade, the engineer in charge of the fire pumps and the shop superintendent, so that immediately all of the trained force may be on duty. The average time taken to get sixteen men and two streams of water at any point of the property is less than two mintues after turning in the alarm.

### ELECTRICAL EQUIPMENT.

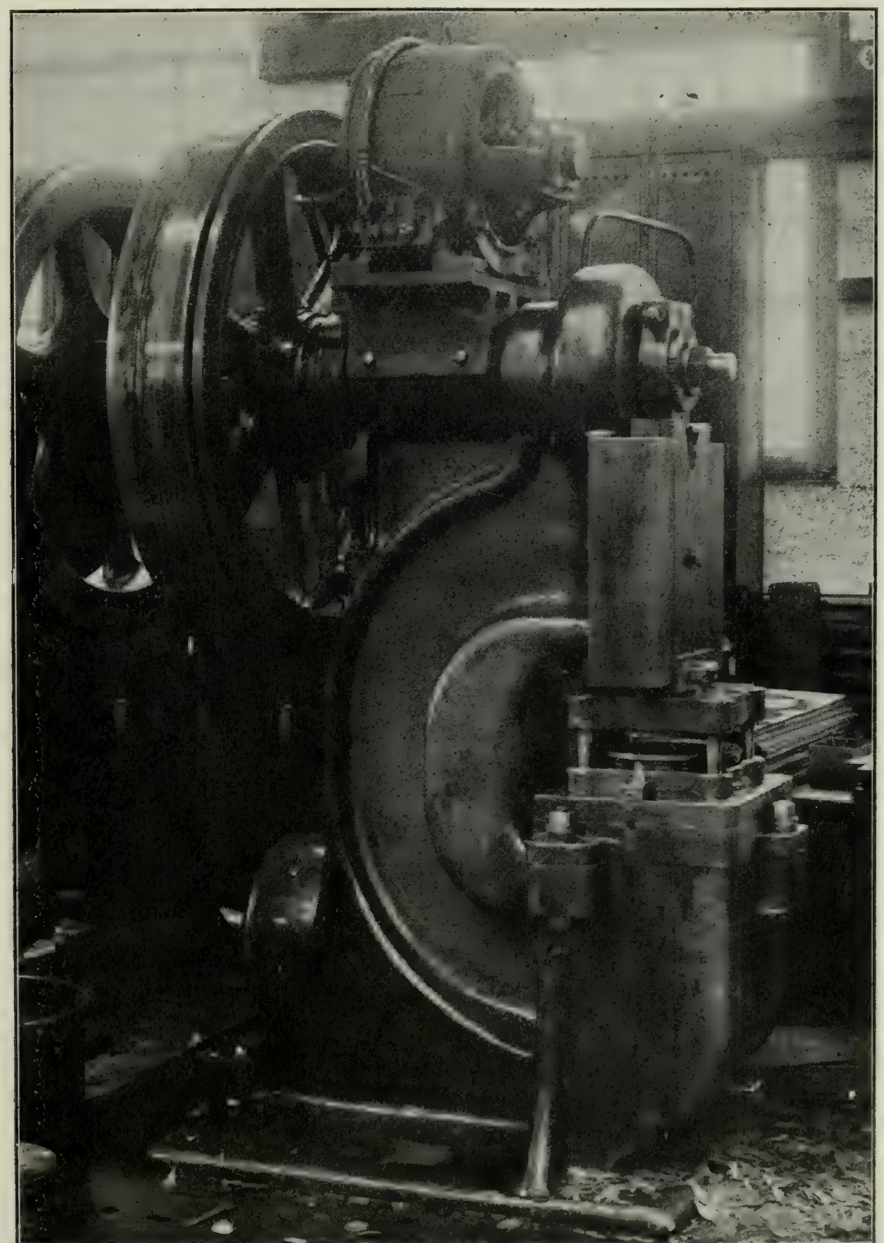
The four generators located in the engine room are of the Western Electric Co's. "L" design, and have several features of especial interest. The pole-pieces are laminated, and the frame is cast around the assembled poles, a novel method of casting being employed. With cast-in pole-pieces, trouble is usually experienced in securing a completed frame having equally spaced poles, as the shrinkage strains are apt to distort the pole setting, resulting in unequal distances between the tips of the poles. To prevent this irregularity the poles of these machines are assembled in a heavy cast iron clamp which is placed in the mould. The arrangement is such that the shrinkage strains are taken up in the yoke and do not distort the position of the pole-pieces, thus assuring uniform air-gap flux distribution, a condition necessary for satisfactory operation.

That part of the armature conductor lying outside of the armature core has an enlarged section, while that part lying inside of the core has a reduced section over that usually employed in machines of these size. By this means a shallow slot is obtained, thus reducing the reactance of the coils during commutation and producing conditions essential for sparkless range. The effect of the enlarged sections at the ends of the armature is to increase the radiating surface of the coil, and by reason of the high conductivity of copper, to draw from the armature core the accumulated heat; thus permitting of large overload capacities with a minimum temperature rise.

As the length of that part of the coil lying outside of the core is approximately 66% of the total length, there may be obtained by reason of the enlarged section a minimum armature resistance, and consequently a maximum efficiency.

The main switchboard, located on the gallery in the engine room,

consists of eighteen 30 in. by 78 in. marble panels placed 15 ft. above the floor. The four generator panels each have a circuit breaker, ammeter, rheostat and two single-pole switches. There is mounted on a separate panel a station ammeter, recording watt-

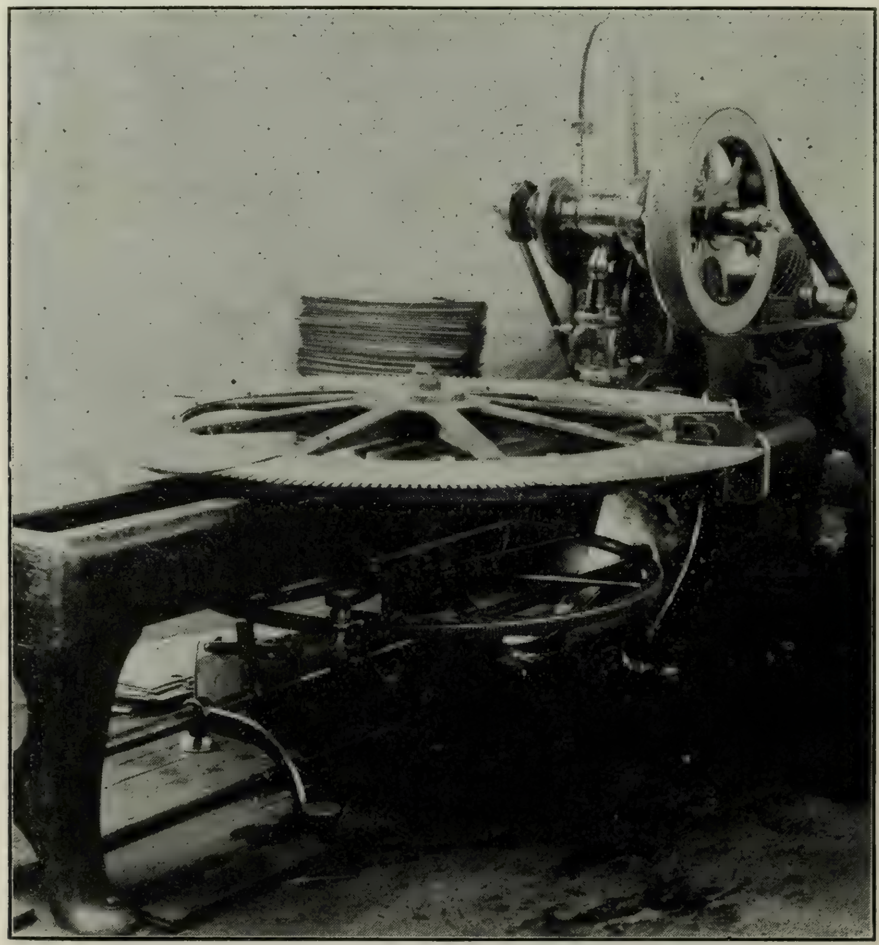


Bliss No. 5 Press.

meter and recording volt-meter. The remaining panels feed the different sections of the plant, each panel controlling two departments. Each department feeder has its own ammeter, recording watt-meter and circuit breaker. By this system a record is kept of the amount of power required for each department. The main station volt-meter is common to all circuits.

As the generators operate at 230 volts, the main switch-board is so arranged that the two smaller units may be operated in the series so that 550 volts may be available for testing purposes, the shunt field coils being of sufficient capacity to permit of an increase in the terminal voltage of the machines.

The various buildings are connected with the power house by a system of well lighted and ventilated tunnels in which are located the telephone, lighting and power cables, and pipes for the drinking,



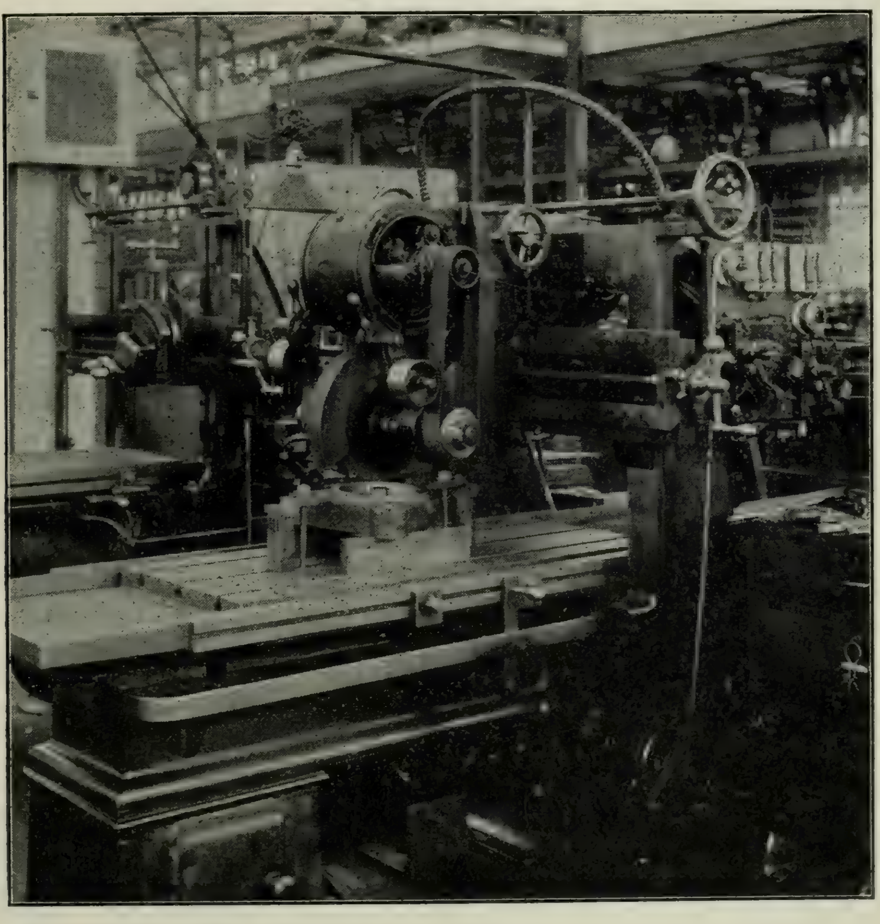
Ferracute Punch, Slotting Armature Discs.

city and house water, compressed air, live and exhaust steam, vacuum and trap returns, roof drain and hydraulic elevators. These tunnels have a uniform height of 7 ft., and vary in width from 4 to 10 ft.

Connecting with the tunnel leading to the machine shop, is a system of concrete trenches surrounding the iron plates of the testing floor. Within these trenches are cables leading into junction points at which are available for testing purposes all voltage from 30 to 600 volts, both direct current and alternating current of 25 and 60 cycles.

The yard and building illumination consists of arc lamps, two in series on 220 volts, and incandescent lamps for local lighting.

All of the machinery in the entire plant is electrically driven, an individual drive system being employed except in a few cases. The main machine shop and cable plant contains many variable speed motors which are operated from a three-wire system. A compensator, or voltage balancer, located in each of these buildings, is of sufficient capacity to carry the unbalanced load resulting from the variable speed motor load.



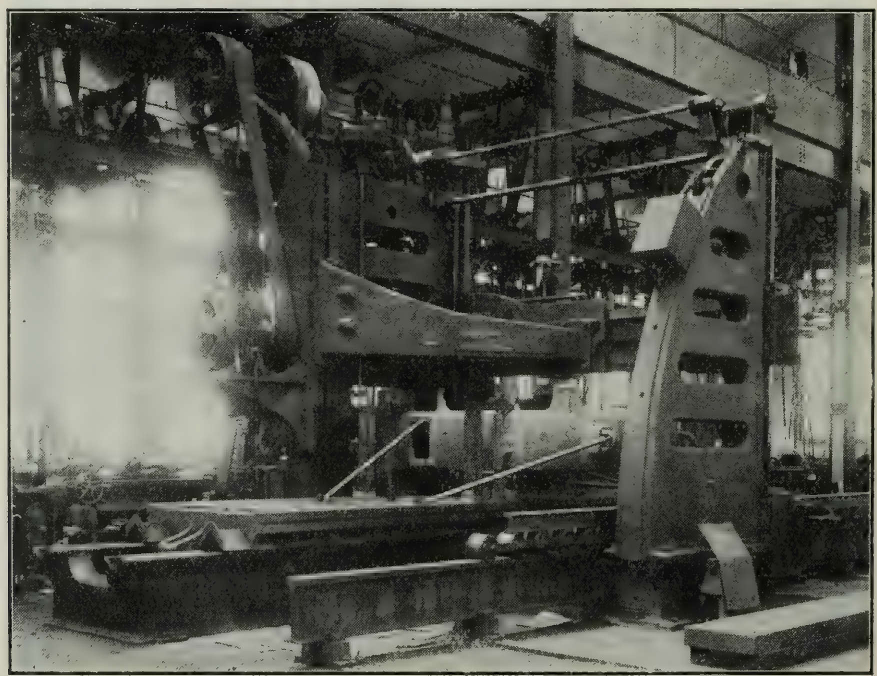
Springfield Surface Grinder.

The voltage balancer consists of two 115 volt machines connected in series directly across the mains, with the neutral wire connected between them. The machines are compound wound, the series fields being connected in the neutral wire.

The forge shop is equipped with electrically driven cold saw, shears, bull-dozers, blowers for forges and two cutting off machines. One of these is equipped with a 1½ H. P. 4 to 1 variable speed motor operating on a three wire system.

In the machine shop will be found an E. W. Bliss No. 5 press, driven by a 5 H. P., 1,000 R. P. M. motor, mounted on top of the

press frame and direct geared to the machine through an internal gear on the fly-wheel, which meshes with a pinion on the motor. Another interesting example is a Ferracute Machine Co.'s punch press used for slotting large armature discs. It is driven by a protected type ¾ H. P. variable speed motor belted to the fly-wheel of the machine. There are also several sheet iron shears found in the machine shop, where the driving motor is of the protected type, delivering 2 H. P. at 1,850 R. P. M. It is mounted in an inverted position on the under side of the machine table, and is direct geared through a raw-hide back gear to the main driving shaft of the machine.



Large Open-Side Planer.

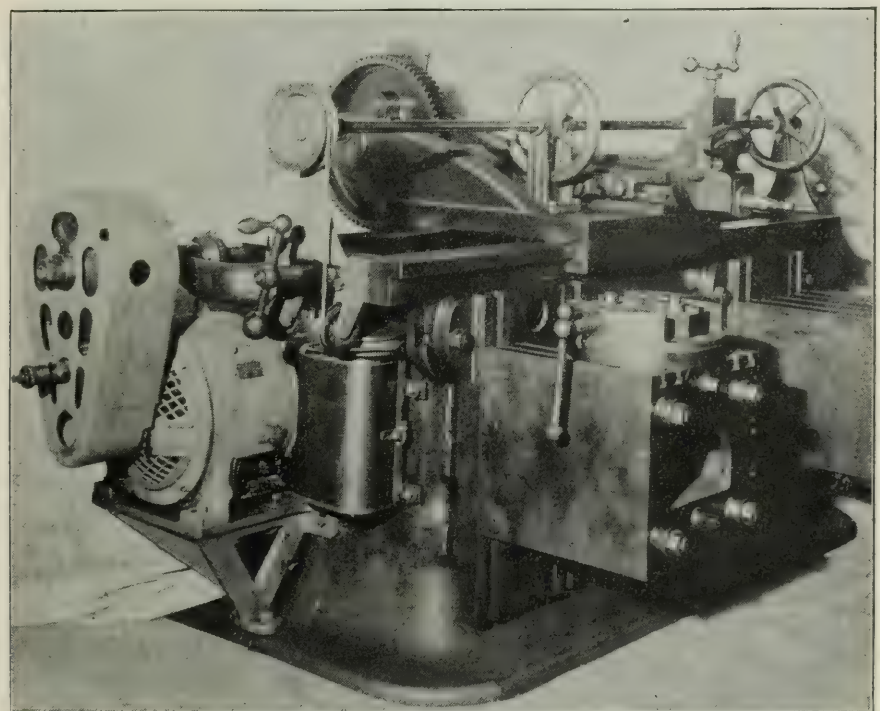
Motor-drive is again illustrated by a Springfield Surface Grinder, the main motor of which is a 2 H. P. at 850 R. P. M. It has a pulley at each end, and both of these pulleys are belted to the spindle of the grinding wheel. The motor is mounted on the grinder head and travels with it across the work. On about the same level with the main motor, behind the housings, there is an auxilliary motor mounted on a bracket, and direct geared, through an internal gear, to the shaft which carries the open and cross belts for the reversible bed travel of the machine.

An example of a small machine, individually driven, is a Pratt & Witney surface grinder, with a 6 in. grinding wheel, direct coupled by means of a flexible coupling to a ½ H. P. motor at 2,600 R. P. M.

Among the largs machine tools located in the machine shop, may be mentioned a Dietrich & Harvey open side planer 120 in. by 24 ft.,

driven by a 40 H. P. open type motor, at 950 R. P. M. The motor is mounted on a bracket on the housing, high enough to be out of the way, and is belted to a counter-shaft on the machine. There is also a 3 H. P. motor on top of the housings, which serves to raise and lower the cross-head.

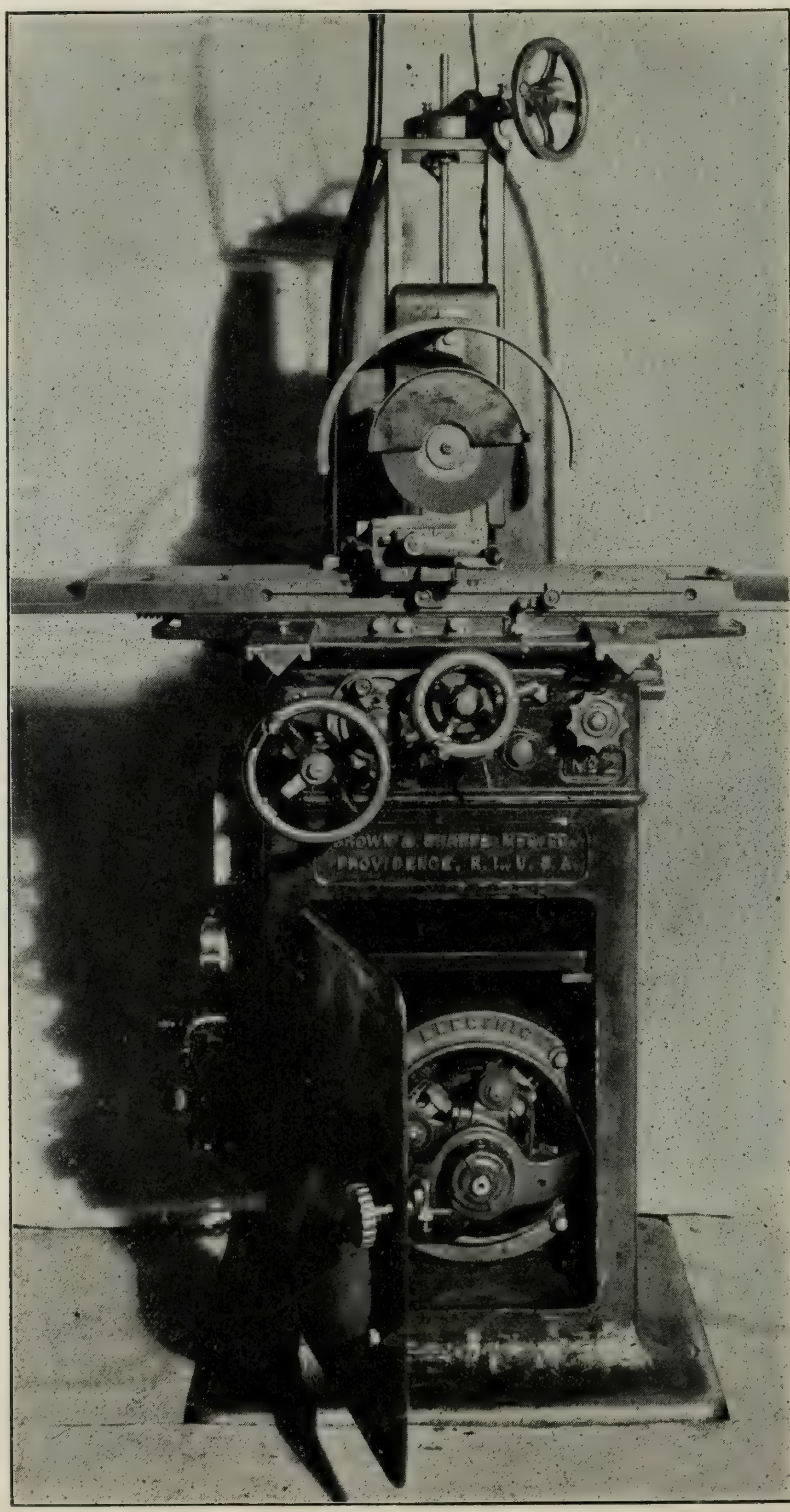
A large Niles' extension boring mill is also electrically driven. The main motor, rated at 10 H. P., is below the floor and drives the boring mill through spur gearing. A small auxiliary motor of 3 H. P. capacity is mounted on the rear bed-frame of the machine, and is geared to the traversing screws for raising and lowering the cross-heads, and for traversing the housings. Near this Boring Mill is a row of eight Gisholt Turret Lathes, with 5 H. P. variable speed motors to drive them. On the rear of the bed, below the head-stock, is a small auxiliary motor for traversing the turret.



Traverse Shaper.

Further on is the single headed traverse shaper which is direct geared to a protected type 1½ H. P. 4 to 1 variable speed motor. A considerable speed reduction is obtained by a back-gear, which is within the gear case. A drum type controller is actuated by a cord passing twice around a drum on its shaft, and also around a drum on a splined shaft on top of the machine, which carries two hand wheels, one at the right hand end of the machine and the other on the shaper carriage.

A Lodge and Shipley 18 in. lathe, direct geared to a 4 H. P. variable speed motor is also of interest. The numerous grinders




Brown & Sharp Surface Grinder.

used in the foundry, machine shop and forge shop are all motor driven.

Mounted inside of the pedestal of a Brown & Sharpe Surface Grinder is a motor with a belt passing around it to a set of counter-weighted pulleys on the grinder spindle. In this way the grinder may be raised or lowered to suit the height of work, while maintaining the proper belt tension for all positions.

Among the portable machines is a large boring and drilling machine, manufactured by the Newton Machine Tool Works. The machine is entirely self-contained, being provided with an arc lamp, as well as motors for power. It has two heavy stirrups, one at each side of the frame near the top, so that it may be easily picked up and carried about by the travelling crane.

In the Insulating Department of the Cable Plant are located eighty special insulating machines, each having five heads operating simultaneously to insulate five wires. The arrangement is such, that two machines are driven by one motor, a 3½ H. P. variable speed, operated by a specially designed controller.

After the wires are insulated, they are twisted together in pairs by the twisting machnies. The driving motors are of the encased type, 1 H. P. at 1,300 R. P. M., and operate the twisters through spiral gears. On the end of each machine frame, above the motor, is a solenoid self-starter which is operated from two push-buttons, one for starting the other for stopping the motor. The operators thus have the machines under instant control.

In the room adjoining that containing the twisters are located the cable twisting machines. The largest one of these machines will carry nearly 600 spools of twisted pairs of wires. This machine is belted through a line shaft to a motor of 30 H. P., 625 R. P. M. capacity. Each of the large rotating reels, which carry a number of wire bobbins, is separately belted to the line shaft by means of a cone pulley on the machine and another on the line shaft.

In the lead covering department there are several 30 H. P. slow-speed motors, each direct connected to the crank shaft of a high pressure pump operating a hydraulic press used in the process of covering the cables with lead casings.

The lead covered cable as it is delivered by the presses, is wound upon large wooden reels for shipment. Each reel is driven by the contact due to its own weight upon a pair of motor-driven parallel rollers, whose upper surfaces are on a level with the floor. The motor which drives these rollers is below the floor and operates the rollers through a worm gear. It is controlled by a special mechanism operated by push-buttons held by the operator while directing the cable. The special mechanism consists primarily of a 1-12 H. P. reversible motor, the extended armature shaft of which is threaded, and drives a controller contact over the segments of a controller.

The wood-working machines in the pattern shop are driven in-

dividually by electric motors, which are encased in square wooden boxes, protecting the motors from dust and shavings. An exception to this general plan, is a motor hung in an inverted position from the ceiling driving line and counter-shafts, to which are belted wooden turning lathes, grind-stones, disc and emery grinders, sticker and planer-knife grinding machines. All the motors, with one or two exceptions, are provided with Cutler-Hammer self-starters, mounted in an asbestos lined case with glass doors. The automatic starter is connected by a snap-switch in the most accessible place that can be found for it on the machine.

The rubber plant has several examples of large machines electrically driven. In the department where the crude rubber is washed, there are a number of colanders, each geared to a 20 H. P., 670 R. P. M. motor; also several dust grinders, geared to a shaft under the floor, which is connected through a spur gear to a 200 H. P. motor, located in a pit of sufficient depth to permit this connection by a single reduction.

In an adjoining room, a 200 H. P. motor located below the floor, drives through positive gearing, five rubber grinders; each of which may be thrown in or out of service by means of a large clutch. A smaller grinder is individually driven by a 50 H. P., 600 R. P. M. motor, through a raw-hide pinion and double reduction.

A double tin-foil mill, is direct geared through a double reduction of spur gears to a 200 H. P., 450 R. P. M. motor. The large gear is about 10 ft. in diameter, with a 12 in. face.

## DISCUSSION.

*Mr. Scheible*—Are all the machine tools direct driven?

*Mr. King*—Not at all; some are direct driven and others are driven in sections; the great majority are direct driven, however. Some are belted in groups.

*Mr. Scheible*—How is the wire run to the various machines?

*Mr. King*—In conduits under the floor in general, and in exceptional cases on the floor in tunnels; all coming from the underground connections.

*Mr. Miller*—To what extent has the relative economy been determined as between individually direct driven tools in the smaller machines, and the usual driving, using larger motors and line shafting? I cannot help doubting the ecnnomy when it comes to small units, and when it comes to machines that work under variable load, you might require a motor of much larger capacity than was needed nine-tenths of the time.

*Mr. King*—I think Mr. Miller's doubts are justified. But economy is not the all-important factor, as oftentimes it is convenience that is desired. The most of our individually driven tools are located in places where a belt or line shafting would be impossible on account of the desired crane service. We have several departments that are group-driven, and they are located under the

south gallery. The second floor of the south gallery is also individually driven.

The best economy cannot be realized by individual driving from small motors of a department working to a small per cent. of its full capacity. Where grinders and small drills are used occasionally and are located convenient for the larger tools, individual driving is the thing to have.

The plant, it will be noticed, extends over a large area and is driven throughout by electric power.

*Mr. Scheible*—Has provision been made for artificial light at the various machines?

*Mr. King*—Yes. I mentioned that the individual lighting is by incandescent light, 220 volts, and the general lighting is by two arc lamps in series.

*Mr. Scheible*—How are those incandescent lights supported?

*Mr. King*—They come up from the floor in conduit and are supported by pedestals with swinging arms.

*Mr. Miller*—What arrangements are made for providing against waste of light on individual machines that are used only a portion of the time? My experience has been that unless great care is taken you will find nearly all the lights burning all the time. This matter of waste of light has become a serious problem.

*Mr. Spurling*—(Called upon by Mr. King).

As a general proposition we have lights to illuminate the entire shop. Most of the lights are arc lamps, which give general illumination, and individual incandescents are made use of only where it is necessary for a man to see his work on the machines. In such cases we depend on the man turning out the light when it is not needed.

*Mr. Miller*—I have known of companies employing a man to go continually around the shop turning out the lights. This proved to be a means of considerable saving. You cannot depend upon the workmen to turn out the lights when they finish using a machine.

*Mr. McMeen*—How many employees are there in these Haw thorne Shops?

*Mr. King*—Approximately 5,000. In the Clinton Street factory there are about 10,000, and in the New York factory about 7,000.

*Mr. McMeen*—That makes about 22,000 employees in the two cities.

*Mr. Scheible*—How do you transport materials from one building to another?

*Mr. King*—We have a railway operating in the buildings devoted to the manufacture of generators and motors.

*Mr. Scheible*—Is it a man-pushing railway?

*Mr. King*—We have a steam car system, connecting all parts of the grounds, standard gauge, taking the cars from the Belt Line and Burlington Road. We have our own locomotive, and there

is a system in vogue by which the car leaves at a certain fixed hour from one part of the plant to the other, and materials which are to be transported are to be placed in that car.

*Mr. Miller*—Have you had any trouble in regard to labor problems?

*Mr. King*—We have had no great difficulty. I think, in general, the class of labor obtained in the suburbs, at the location we have, is a little higher grade than down town. Our men in general are those owning homes in near-by places.

In reference to the matter of transportation, from the City to the Hawthorne Shops—there is the Chicago, Burlington & Quincy Railway service, which is fairly good for the morning and evening hours, but during the middle of the day, the only service available is by the Ogden Avenue surface line, or by the Metropolitan Elevated, Garfield or Douglas branches, with a surface line from their terminals to the works.

*Mr. Scheible*—Referring to Mr. Miller's remarks concerning difference in insurance rates between the Clinton Street and Hawthorne plants, can you tell us what the difference is?

*Mr. Hitchcock*—About ½ cent more per hundred. At Hawthorne, our insurance costs us about 5 cents and at Clinton Street about 5½ cents, a difference of 10%.

# THE ASSESSMENT OF DRAINAGE DISTRICTS.

L. E. Ashbaugh, M. W. S. E.

*Presented June 6, 1906.*

The increasing interest in the drainage of farm lands and especially the construction of the large drainage ditches and of tile drains under county control has caused this subject of assessments to be of much importance. It is therefore proposed in this outline to suggest certain principles which may govern the distribution of expenses over the various tracts, as well as to give an arithmetical method for actual solution of the problem. The general principle to be followed is that which is common by statute to all states, namely: that *assessments must be proportionate to the benefits received.* It therefore devolves upon the commission of assessors to determine proportionate benefits on the various tracts of land within the drainage district; also upon highways, railways and similar property.

The laws of Iowa (and of some other states) demand that the report of the assessors to the Board of Supervisors shall give a classification percentage which shall be 100 per cent on that tract of land which receives the greatest benefit, and proportionate percentages on all other tracts. The object of this percentage classification is held to be not alone a means for determining the present assessments, but of more importance for future use in case of an additional assessment which must be levied over the entire district for some purpose which affects the entire district in the same way as does the original construction. In case a new assessment must be made which does not thus affect the entire district, the statute expressly provides that the board of supervisors shall have power to cause a new classification percentage to be made. By the method to be here given the amount of assessment on the various tracts will be found, and that tract which has the largest assessment will then be marked "100 per cent" and other tracts proportionate.

## *Common Factors.*

While there are many factors which have a part in determining the amount of each assessment, the following three factors are common to all districts.

1st. If the drainage improvement is so designed that either by present construction or by future extension all of the wet land within the district will be reclaimed, then the land will be benefited in proportion to its intrinsic need for drainage, the lowest, wettest land being marked "100 per cent." (Table I, Col. 4). In case the present improvement is not sufficient to drain all land properly,

(e. g. if the grade line is not low enough) then that land which receives the greatest benefit as regards changing the character of the land will be marked "100 per cent."

2nd. The land will be benefited in proportion to its proximity to the improvement, the land directly on the improvement receiving immediate benefit, therefore being marked "100 per cent," (Table I, Col. 5), while land at some distance from the improvement will be marked a lower per cent.

3rd. The land will be benefited in proportion to its distance from a *natural* outlet of its own, the land most remote from such *natural* outlet being marked "100 per cent" (Table I, Col. 6), while land near such outlet will usually be marked a low per cent as it receives the benefit of only a part of the improvement.

*Solution for an Assumed District.*

Referring to Figure 1, let us assume a drainage district with outlet at the south side of Section 22, the upper end of the drain

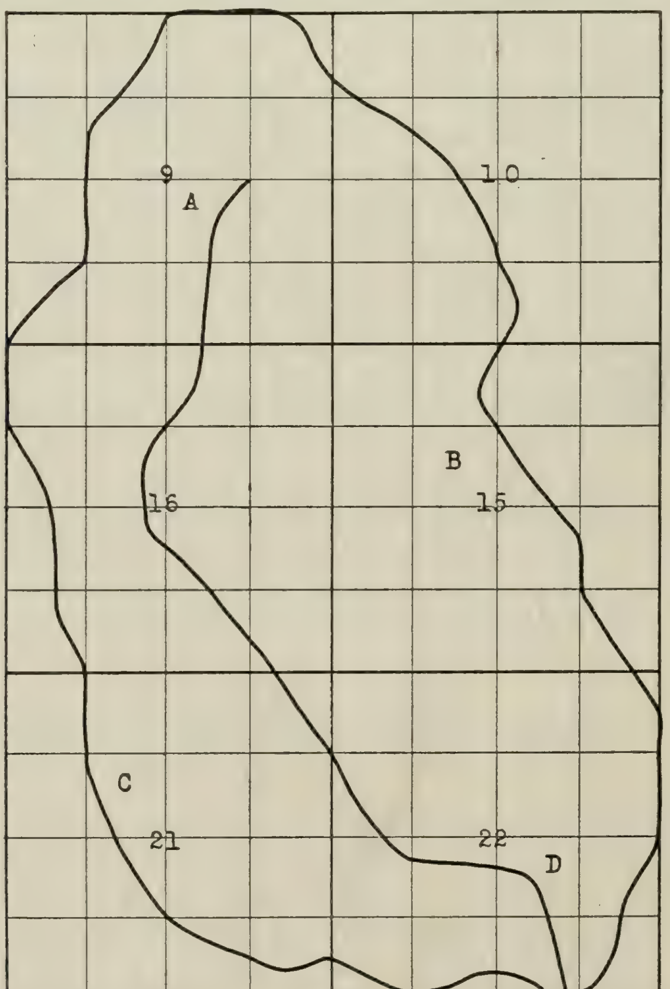



Fig. 1. DRAINAGE DISTRICT.

TABLE I.—ASSESSMENT OF A DRAINAGE DISTRICT.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| Owner. | | FACTORS. | | | | | | | |
| | Description. | Acres. | Character Land. | PROXIMITY. | | Product Factors. | Sum for Tract. | Assessment. | Classification Per Cent. |
| | | | | Drain. | Outlet. | | | | |
| A | N.W.-S.E. 9 | 6 | 100 or 3/3 | 100 | 100 | 6 00 | | | |
| | | 12 | 2/3 | 100 | 100 | 8 00 | | | 100 if Maximum. |
| | | 15 | 1/3 | 90 | 100 | 4.50 | | | |
| | | 7 | 0 | | | | | | |
| | | 40 | | | | | $18.50 | $245.00 | |
| B | S.E.-N.W 15 | 6 | 3/3 | 10 | 65 | .39 | | | |
| | | 12 | 2/3 | 10 | 65 | .52 | | | |
| | | 15 | 1/3 | 10 | 65 | .32 | | | |
| | | 7 | 0 | | | | | | 6.6 |
| | | 40 | | | | | 1.23 | 16.00 | |
| C | S.E.-N.W 21 | 4 | 2/3 | 50 | 50 | .67 | | | |
| | | 10 | 1/3 | 50 | 50 | .83 | | | |
| | | 18 | 0 | | | | | | 8.1 |
| | | 32 | | | | | 1.50 | 20.00 | |
| D | N.W-S.E 22 | 6 | 3/3 | 100 | 20 | 1.20 | | | |
| | | 12 | 2/3 | 100 | 20 | 1.60 | | | |
| | | 15 | 1/3 | 90 | 20 | .90 | | | 20.0 |
| | | 7 | 0 | | | | | | |
| | | 40 | | | | | 3.70 | 49 00 | |
| | | | | | | | Etc. | Etc. | Etc. |
| | | | | | | | 1280.40 | $17000 | |

being just east of the center of Section 9. Referring to Table I, it will be noted that column 1 gives the name of the owner, while column 2 gives the description of each tract, be it forty acres or less according to any natural or recognized subdivision. Columns 3 and 4 show the subdivision of each tract into various classes of land, in this case using four classes, namely: the very wet or slough land which will receive maximum of benefit, therefore marked "100 per cent or 3/3 in column 4; the "wet land" which is of such character that it will receive two-thirds as much benefit; the "low" land which will receive one-third as much benefit, and the "dry" land which is commonly rated to receive zero benefit. (A method for assessment of dry land due to general benefit will be given later.) For purpose of comparison let us assume that the tracts A. B and D, each having forty acres, are similarly classified, each estimated to have six acres of the "100 per cent" or "3/3" land, twelve acres of the "2/3" land, fifteen acres of the "1/3" land, and seven acres of the "zero" land. Tract C on the outer edge of the drainage district has only thirty-two acres. As regards character of land and its intrinsic need for drainage, columns 3 and 4 give the required data.

Column 5 shows factors which represent proportionate benefits on account of proximity of drain. It will be easily recognized that tract B receives very little benefit from this improvement as compared with tracts A or D, therefore the first two classes of land in tract A are rated at 100 per cent because the drain goes directly through such tracts. As a suggestion the fifteen acres of 1/3 land

are rated at 90 per cent, it being sometimes noted that this low land lying back from the slough will require still further improvements in order to render its soil as good as will be that nearer to the improvement. A similar classification is made for tract D. Tract B lying a mile back from the drain is here given a rating of 10 per cent. This is suggestive only. It might perhaps be twenty per cent or as low as three per cent. Tract C lying at a lesser distance from the drain than tract B is given the suggestive rating of fifty per cent. In column 5 then is given the estimated comparative ratings due to the benefits which the various tracts will receive on account of proximity to such improvement.

There may seem to be at this point a conflict with the Statutes of Iowa which provide that we "shall not consider what benefits such lands will receive after some other improvements shall have been constructed, but only the benefits which will be received by reason of the construction of the improvement in question as it affords an outlet for the drainage of such lands." The second clause of this quotation must be recognized as fully as the first. It is not proposed to assess land lying back from the improvement for anything more than the benefit it derives on account of an outlet which is brought to a nearer point than the former outlet. Land remote from the improvement is benefited because of its new and more accessible outlet, though the actual condition of the soil may not be changed in any respect until further extension of the improvement is made. In the same way is farm land benefited when a new railroad brings its warehouses and markets to within a short distance of said farm where before such privileges were a long way distant. The character of the soil and the farm improvements are not changed in any respect, but the farm becomes more valuable because of a more accessible market and distributing point. In this way are all parts of the drainage district benefited, even though remote from the present improvement.

Column 6 gives the comparative ratings for benefits on account of outlet. If this district has a gradual fall from the upper end to its outlet with no sudden slopes or hills, then will the tracts at the upper end receive the maximum of benefit on account of outlet. The tract next to the outlet receives benefit from the improvement above in so far as overflow is prevented. On many of our districts the tract at the lower end receives very little benefit from the improvement above. An outlet to a tile drain may be of great benefit as it may furnish running water for stock throughout the entire year. As a suggestive figure, tract D is here (column 6) rated at 20 per cent, tract C 50 per cent, tract B 65 per cent, and tract A 100 per cent on account of benefit of outlet. If tract A had a good outlet of its own, for example, on to the tract just below it, then A would be assessed a small amount because it would receive little benefit from the construction of the drain below, and the tract just south of A would then perhaps become the "100 per cent tract" on account of the outlet. The principle is simply this, that that tract

of land which will receive the greatest benefit on account of an outlet, taking into account the distance from a natural outlet and the length of improvement necessary for drainage, will be rated at 100 per cent.

Columns 3, 4 5 and 6, therefore, give the various factors which are common to most drainage districts. On the basis of an assessment of one dollar per acre on that land most benefited, the 6 acres in tract A would be assessed $6.00 (column 7), this result being obtained by multiplying together the factors. The 12 acres of tract A would be assessed $8.00, the 15 acres $4.50, making a total on this one dollar basis of $18.50 against tract A. As a comparison, tract B, having similar acreage but located a long distance from the drain and not so far from the outlet, would be assessed $1.23. Tract D, having similar acreage located on the drain but near the outlet, would be assessed $3.70. By similar figures C would be assessed $1.50. Taking all of the tracts of the drainage district, let us assume that the sum available on this one dollar basis is $1280.40. Let us assume too that the estimated cost of the improvement, less the lump sum assessments for railways, highways, etc., is $17000.00. Then will column 9 give the actual assessment against each tract, these figures being found from column 8 by using the ratio between the summation figures at bottom of columns. It is sufficient to make these final calculations to the nearest dollar.

As before noted the statutes of Iowa require a classification percentage. Therefore, by noting either in column 8 or column 9 the maximum amount, place opposite that amount in column 10 the figure "100," assumed in this table to be for tract A. On this basis tract B would then be rated at 6.6 per cent, tract C at 8.1 per cent, while tract D would be assessed 20.0 per cent. This classification percentage is held to be made with respect to the amount of the assessment but without respect to the magnitude of the tract. If for any purpose it is desired to make a comparative rating per acre, then will the 8.1 per cent for tract C be increased in the ratio of 40 to 32, making 10.1 per cent, there being only 32 acres in this tract as compared with 40 acres in the others.

Columns 9 and 10 are very readily obtained from column 8 by use of a slide rule, with which every engineer on assessment commissions should be equipped.

## *Other Factors.*

On a drainage district it is possible that some tracts of farm land are located near a town, while others are at a great distance. The value of the land near market is, on account of such market, relatively higher than that at a distance. It may, therefore, be held that the drainage of this land near market is of more benefit proportionally than is the drainage of similar land in more remote parts of the district. If it be desired to take this factor into account,

another column can easily be added to the table here given, placing such between columns 6 and 7, and giving therein such percentages as will express proportionate rating of benefits due to comparative value of land and benefits to be received. This can be extended for other factors.

When a drainage district includes a city or portion thereof, the assessment of city lots will then require careful consideration. By some method the benefit to the city lots must be determined and compared with the benefit to the farm property. The principle of assessment may be thus stated. If a city lot is benefited two hundred dollars while a forty-acre tract of land is also benefited two hundred dollars, then the assessments on these two tracts of land must be equal. This is independent of the areas of the tracts. The general principle must be remembered that *assessments must be proportional to benefits received.*

A special case which may occur is the following. The lower part of the improvement may be an open ditch while the upper part may be a large tile drain. That tract just above the outlet of the tile will receive greater benefit because of the tile than it would if an open ditch were here constructed; therefore the assessment on this tract would be proportionately larger than on the others.

If a tract has been already tiled out and the outlet to the tile will be into the new improvement, then should the tract be assessed for the benefit which it will receive on account of the new and better outlet.

### *The Assessment of Dry Land.*

It is often considered advisable to levy a small assessment on all land within the Drainage District on account of the general benefit, because such improvement is conducive to the public health and general welfare of the entire district, and furthermore the irregular tracts of dry land which may be cultivated will be made square and regular as soon as the proper drainage improvements have been constructed. It is true that much of the so-called dry land would be benefited by tiling and such improvements will doubtless be made in the not distant future. However, our farmers are not willing to admit such possible benefits at the present time and assessors are therefore reluctant to levy such assessments. Some engineers may prefer to assess the dry land a small amount at the time that the assessments on other classes of land are made as in Table I. It is here proposed, however, that an assessment be levied over the entire district. Assume such assessment to be 25 cents or 50 cents per acre, depending on the total area of the district and total cost of the improvement. To the amounts of assessment as given in Table I will then be added the asseessment here made for general benefit, this assessment being made on the wet land as well as on the dry land.

*Assessment of Highways.*

This is perhaps the most puzzling question which occurs on the assessment of a drainage district. It is probable that such assessments are usually only a guess. While no definite rules can be given, some principles may be noted. The assessment should vary with the importance of the road. That road which is a main highway leading to an important market will receive greater benefit from drainage of its roadbed than will an unimportant highway which now is or will later be but little used because of its location. An estimated cash benefit may be computed taking into account the present expense of maintaining the highway after drainage; also the cost of construction of a suitable highway both before and after the construction of the drainage improvement. These maintenance charges expended annually should be capitalized, thus giving the proper sum of money which at ordinary rate of interest will yield the amount necessary to provide for maintenance. The actual cash benefit to some tract of farm property may then be estimated and comparison taken with the benefit which the highway will receive. From these comparative benefits, and noting the assessment on the tract of farm land, the assessment on the highway may be obtained. The cost and maintenance charges of bridges and culverts, both in present condition and after construction of the improvement, must be estimated. The comparative figures will furnish data for determining benefits and also damages.

It does not seem just to assess highways by the acre at the same rate as adjoining farm land. The benefit to the highway does not depend upon the area of the highway. The part of the highway actually used is the 16 or 20 foot width of driveway. It is entirely immaterial whether the highway be four rods wide or half that amount or double that amount. The benefit which the public will receive in using the highway depends upon the condition of the embankment and not upon the distance between the fence lines.

*Assessment of Railways.*

As in the case of highways, there are many factors to be considered, some of which may be only rough estimates. It is held by some that, even if the roadbed and bridges of the railway company may not receive any benefit, still the railway company is benefited because of the drainage improvement over the district which will serve to give increased crops, the transportation of which is the business of the railway. The drainage of a roadbed is certainly of benefit to the railway company, as it renders such roadbed more stable and consequently will require a less annual expense for maintenance. Very frequently the railway company will be able to use a much shorter bridge after the construction of the improvement; this is a factor of great benefit. As in the case of highways, the difference in cost of maintenance of the present and of the fu-

ture structures and the cost of construction thereof must be estimated, the annual charges being capitalized.

These assessments against highways and railways and any general assessment over the entire district are all lump sums which will be subtracted from the total cost of the improvement, the remainder being then distributed over the tracts of wet land, as shown in Table I.

## *Mode of Procedure.*

The method of using the system here proposed may be outlined as follows: Before going into the field the engineer reviews the plats of the drainage district and in his note book makes out an outline for the tabulation of Table I. He records the description of each 40-acre tract (column 2) and the owner thereof (column 1). Going into the field the commissioners review each 40-acre tract and determine the areas of different classes of land (columns 3

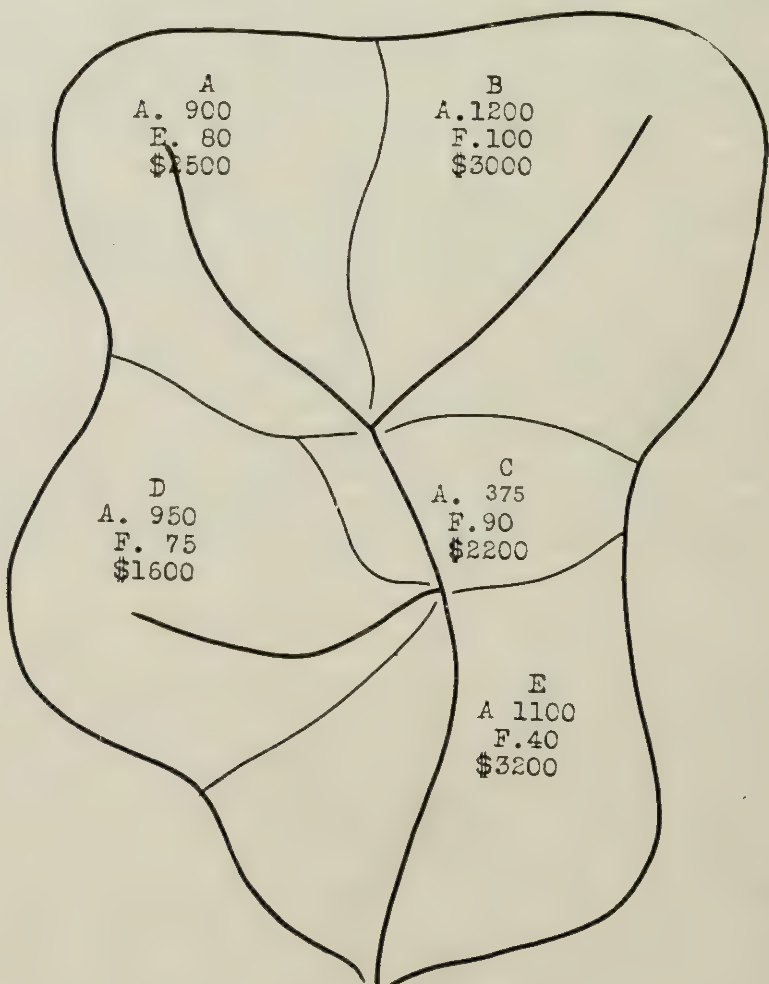



Fig.2. SUB-DISTRICTS.

and 4). The only work done in the field is to determine this classification for character of land. The classification for proximity to drain and outlet is determined after the return to the office. It is often impossible to make a comparative rating for these factors while in the field. This can be very readily accomplished in the office after the field investigations by use of the map, from which may be noted the comparative distances, watershed divides and other topography. The factors thus determined are multiplied together and total assessments calculated.

### THE DISTRIBUTION OF EXPENSES TO SUBDISTRICTS.

Referring to Fig. 2, and Table II, let us assume that we have a drainage district in which there are laterals as shown. In the figure, data is given for each sub-district. For example, sub-district A has 900 acres; the cost of the improvement within sub-district A will be $2,500.00 (F. 80 refers to a factor to be explained later.) As a general principle, but having its exceptions, each sub-district, as A, B or D, should be assessed for its own improvements within its borders. This will hold unless it can be shown that the improvement in some sub-district, as A, will be of benefit to some other sub-district, as B or C. The drain through sub-district C, however, is of service not only to C but also to A and B, therefore, the cost thereof ($2,200.00 for C) should be distributed in proportion to benefits received. As in Fig. 1, let us assume that an acre of land at the lower edge of tract C receives but little benefit from the improvement above, and that an acre of land at the upper edge of tract C receives a maximum of benefit. If the change were gradual from zero to 100 per cent, the average benefit to tract C would then be 50 per cent. In Table II, however, it is assumed that the average benefit is two-thirds instead of one-half. On the basis of acreage take two-thirds of the 375 acres in sub-district C and combine this with the acreage of sub-districts A and B and divide the expenses ($2,200.00) through C proportionately. This is shown in the first part of Table II under the heading "Basis of Acreage." Similarly the expense of improvement through E ($3,200.00) would be divided over A, B, C, D and E, using 2/3 of 1,100 acres in E to combine with the other acreages. In this way will be found the various distributions and in the lower part of Table II is given the total expense to each sub-district. For example, sub-district A is assessed $2,500.00 for its own improvement, $842.00 for its outlet through C, $693.00 for its outlet through E, a total of $4,035.00.

The preceding distribution has been made on the basis of acreage, but let it be assumed that sub-district B contains much more wet land on the average than does sub-district A, then should B pay more proportionately than does A. By an inspection of the various districts it may be possible to determine factors which will represent proportionately the different conditions of the sub-districts.

TABLE II.—SUB-DISTRICTS.

| For Part | Assess to | Basis of Acreage. | | Basis of Factors. | | | |
|---|---|---|---|---|---|---|---|
| | | Acres. | Assess. | Acres. | Factor. | Equiv. Area. | Assess. |
| C | A | 900 | 842 | 900 | 80 | 720 | 738 |
| | B | 1200 | 1124 | 1200 | 100 | 1200 | 1230 |
| | ⅔ C | 250 | 234 | 250 | 90 | 225 | 232 |
| | | 2350 | 2200 | 2350 | | 2145 | 2200 |
| E | A | 900 | 693 | 900 | 80 | 720 | 706 |
| | B | 1200 | 924 | 1200 | 100 | 1200 | 1177 |
| | C | 375 | 288 | 375 | 90 | 338 | 332 |
| | D | 950 | 731 | 950 | 75 | 712 | 698 |
| | ⅔ E | 733 | 564 | 733 | 40 | 293 | 287 |
| | | 4158 | 3200 | 4158 | | 3263 | 3200 |

TOTALS.

| To District | For Part. | By Acreage. | | By Factors. | |
|---|---|---|---|---|---|
| A | A | $2500 | | $2500 | |
| | C | 842 | | 738 | |
| | E | 693 | $4035 | 706 | $3944 |
| B | B | 3000 | | 3000 | |
| | C | 1124 | | 1230 | |
| | E | 924 | 5048 | 1177 | 5407 |
| C | C | 234 | | 232 | |
| | E | 288 | 522 | 332 | 564 |
| D | D | 1600 | | 1600 | |
| | E | 731 | 2331 | 698 | 2298 |
| E | E | 564 | 564 | 287 | 287 |

This can be much more accurately determined, however, by a review of columns 3 and 4, Table I, which columns give the acreages for different classes of land.

Let it be assumed that sub-district B averages more wet land than any other. Therefore, rate this sub-district as 100 per cent. Assume sub-district A to rate 80 per cent, C 90 per cent, D 75 per cent, and E 40 per cent. Instead of distributing the expense over the various sub-districts in proportion to the acreage, we may allow for this difference in character of land by multiplying the various areas by their respective percentages, which will give equivalent comparative areas. By a method of procedure similar to that used on the "basis of acreage", distribute the expense, using these new equivalent areas. Table II shows that B would then be assessed $5,407.00 on the basis of factors and only $5,048.00 on the basis of acreage, the factor basis taking account of the wet character of the land.

A very common case in connection with construction of a drainage improvement is that not all of the laterals are put in at time of first construction, but the main ditch is properly designed to provide for all future laterals. Assuming that the lateral into sub-

district A is not constructed, the proper assessment against sub-district A should then be its proportionate share of the expense through C and E, being $842.00 plus $693.00 or $1,535.00 on the acreage basis, or $1,444.00 on the factor basis.

The distribution of total cost to each sub-district over the various tracts within such sub-districts is important. Considering the amount $4,035.00, obtained for sub-district A on the acreage basis, the first part, $2,500.00, should be distributed by the method of Table I, using ratings for proximity to outlet as there shown, the outlet to sub-district being considered. The other parts, $1,535.00, being cost of construction through C and E, should be distributed by the same mthod, Table I, but using a factor 100 per cent for all tracts as regards outlet, thus giving column 6 a constant value. The work may be made much more simple and of sufficient accuracy by the following method, using an example from Table II:

For A, the cost of construction through C and E is $1,535.00, or 38 per cent of the total $4,035.00. Mark that tract of land 38 per cent (Col. 6), which receives zero benefit on account of outlet due to the construction of the improvement through A. Mark the tract most benefited 100 per cent, and to all others give proportionate values between 38 and 100 per cent. If there is to be considered no tract of zero benefit then will the tract least benefited be rated something above 38 per cent and proportionately between 38 and 100 per cent, depending on the estimated rating due to the part through A.

## APPRAISEMENT OF DAMAGES.

Our statutes insist that the commission which assesses damages shall give no thought whatever to any benefits, and that the commission which assesses the benefits shall not think of the damages. While the subject of this paper is the assessment of benefits, it may not be inappropriate to mention a few factors which may be considered as causes for damages.

A tile drain across a field is of damage only in so far as does the construction of such tile drain interfere with the crops and farming operations. An open ditch, however, is an obstruction for all time, and like the right of way for a railway company may be considered just cause for damages. It is held by some that land which is of little present value is, if used for a drainage ditch, subject to award of damages only for such present value. However, the assessors of benefits will assess the land for the benefit that it will receive without regard to the fact that a certain area thereof is to be used for an open ditch. Therefore should the land be paid for at the rate of value which the land will have after construction of such ditch. This may be further illustrated as follows: Supposing that a property line between owners A and B runs along the middle of a draw or slough. If the ditch is located entirely on A's land then B will get the full benefit of the ditch without giving up any of his land, whereas if the ditch had been entirely

on B, A would have received the full benefit without loss of land. Similarly do parties owning land back from the ditch get the benefit of the ditch as an outlet without giving up their land for such ditch. For this reason should the right of way taken for the ditch be purchased, the rate of payment being that of the value of the land after improvement has taken effect.

There are other damages due to an open ditch. The ditch itself cutting across fields, perhaps diagonally, is an obstruction for farm operations for all time to come. Waste banks are unsightly and are a possible injury to the adjoining fields. Extra fencing must be put in to keep stock from the ditch. Bridges will be needed in order to give access to property "beyond the ditch." All of these factors are to be considered in estimating the damage due to construction of an open ditch across a farm.

In awarding damages to a railway company many factors are to be considered and these are often as indefinite as are those for the assessment of benefits against such companies. If the company is required to build a new bridge there will be damages on this account. If the company will be required to take up a bridge to allow the passage of the ditching machine there will be a just claim for damages. If the company is required to pay the expenses of constructing the improvement across its own right of way, such cost will be a just claim for damages. In few cases, however, does it seem necessary to put in a steel bridge of long span to replace a present timber structure of several short spans, this change to be made at the expense of the drainage district. By making the ditch a little wider at the point of crossing the railway right of way pile bents may often be put into the channel of the ditch, thus permitting the use of a pile trestle similar to what may now be in use.

It will be noted that benefits and damages are in many cases very intimately connected. Damages are awarded because of a change of the railway bridge and benefits are also assessed against the same company for the same bridge, because the new bridge will be, perhaps, shorter than the present bridge. It therefore seems advisable that part of the members of one commission should also be on the other commission, and there are many reasons why it would be advisable to have the same entire commission appraise the damages and assess the benefits.

## THE SURVEY, MAP AND REPORT.

### *Methods of Surveys for Drainage Improvements.*

The method of making the investigaiton of the drainage district relative to a proposed improvement will depend entirely upon the physical characteristics of the district, its extent, the degrees of efficiency of drainage desired as regards whether only a main drain shall be constructed or whether sufficient laterals shall also be constructed in order to give an outlet to every farm within the district, etc. On small districts and perhaps on some of the larger

ones the ordinary method of surveying by tape and transit may be best used. Sometimes levels are taken at the same time, using the transit as a level. On many districts the stadia method of surveying is desirable. As it will not be necessary to use vertical angles the stadia methods are, therefore, very much simplified. This gives a very easy method for locating the boundaries of sloughs and for getting such topography as is necessary. The engineer's level is then used for getting the required elevations. On large districts the "intersection method" may be economically used. By this method a base line is laid off, using either the tape or stadia, and a triangulation system is developed to cover the entire district. From these triangulation points stadia work may be projected or intersections taken to flags (cloth on lath) to give fence corners, boundaries of sloughs, draws, etc. This method has been developed in considerable detail and explanations may be found in a paper by the author given in the Journal of the Western Society of Engineers, Vol. X, page 204, April, 1905, and reprinted in the Engineering News, Vol. 53, page 329.

It is not considered necessary to make a survey by level, taking elevations every 100 feet along any certain line, but it is essential to have elevations of important points over the entire drainage district. These points should include the water level of all ponds and depths of same, levels at strategic points along the natural channels, also lowest points at divides between ponds, draws, etc.. Most of these elevations can be most profitably taken after the map has been prepared, because the map will show the real location of various points and the level will be used to give elevations to show possibilities of constructing the improvement along certain routes, keeping in mind cut-offs and other short routes, many of which would not be noted in the field, but will be apparent only by reference to the map. If the main ditch only is at first constructed it must be so designed that it serve outlying districts by construction of future laterals. Otherwise the ditch may need to be made larger and deeper for such new improvement. The method of designing improvements so that every farm within the district is given an outlet is to be commended.

### *Map.*

It may be said that one main object of the survey is the preparation of a map from which the proposed system may be designed. The survey and the map are, therefore, very intimately connected. The map should be carefully made to scale and should show the entire watershed which is by nature tributary to the proposed improvement; also the divides between the various sub-districts, as it is impossible to design the improvement without such data. Elevations and depths of ponds should be shown, also elevations of the low necks of lands and of all important points of land along the natural channels. A paper location may then be made by the engineer and such a profile platted as will enable him to design

the system. This map will also be of service and usually sufficient in purpose for use of the commission which assesses the benefits, though in some cases it may be advisable to have the engineer make the location survey after the district is established and before the assessment is made, the first survey being preliminary only.

### *Report to the Board of Supervisors.*

The engineer's report should be of such a nature as will show the advisability of establishing the district and constructing the proposed improvement. In addition to the map and a report as to the number of acres within the district and the estimated cost thereof, there should also be some data furnished which will enable the board of supervisors to get an idea as to the cost per acre which will be assessed against various classes of land. In Table III, here submitted and which is used in many counties to advantage, the number of acres of various classes of land is given, also an estimated average assessment from which may be determined the revenue available, or more properly the average assessment is determined which will yield the sum required for the construction of the ditch. In the table it is noted that $8.00 per acre is the

TABLE III.—ESTIMATE FOR PROPOSED IMPROVEMENT.

| Tract. | ACR. DIRECTLY AFFECTED. | | | ACR. INDIRECTLY AFFECTED. | | | |
|---|---|---|---|---|---|---|---|
| | Swamp. | Wet. | Low. | Swamp. | Wet. | Low. | Dry. |
| N. W. 9 | 30 | 20 | 30 | | 5 | 10 | 65 |
| E. ½ N. E. 9 | 12 | 20 | 10 | | | 10 | 28 |
| S. E. 8 | | 7 | 10 | 20 | | | |
| | ... | ... | etc. | ... | etc. | ... | ... |
| Totals | 210 | 390 | 540 | 68 | 240 | 760 | 1320 |
| Assessment | $ 8.00 | $5.40 | $2.70 | $1.50 | $1.00 | $ .50 | |
| Revenue Available | $1680 | $2110 | $1460 | $102 | $240 | $380 | |

$6072 available on 2208 Acres, also 1320 Acres of dry land.
Estimated cost of ditch $6000.

average assessment against swamp land directly affected by the improvement. It is probable then that the maximum assessment will be less than double this amount, or $16.00. From such a table may be determined at once the advisability of constructing the improvement. Acreage data of sufficient accuracy for this report can be readily made up by the engineer after his field investigations.

DISCUSSION.

*Ernest McCullough*—M. W. S. E.—It will be difficult to discuss this paper without having a copy of the statutes of Iowa. The question comes to my mind whether this is a method, that, if reviewed in a court, would hold, or if it is simply a speculation on the part of an engineer as an ideal method for assessing land. In California I had considerable work to do at one time in connection with drainage districts. There was one body appointed to pass on benefits and damages received. As a rule they made a flat rate over all the acreage of the districts for the main drains, regardless of the benefits the land would receive.

Highways, I believe, were not separately assessed, for the public has only an easement in a highway and when the same is abandoned the land goes back to the owners of the abutting property. No attention is paid to the roads, either public or private. The railway right of way is simply an easement, and the title will revert to the owners, or their heirs, if the right of way is abandoned. However, so long as it is occupied for railroad purposes it technically belongs to the railway company and the assessment should be levied against it on an acreage basis. The question of damage to the railway company had to be proved. The railway company was content to pay its proportion of the cost for all benefits received, and the board would put in a report that the benefits were so and so, and the damages were nothing, and the cost was levied over the entire district.

Of course, the methods for benefits would be applicable to any state in the Union, provided the statutes were of such a nature that the method could be applied. We do not know whether they have had any experience in Iowa in assessing benefits, according to this method described by Mr. Ashbaugh. I should judge there might be some people who would carry the matter into court in any event, might think the assessment was levied in too technical a manner. Generally the courts decide that an assessment will stand if equitable in the main. But as a rule the method that is most easily understood and comes nearest to levying a flat rate is the one that meets with most favor.

The case is quite similar to some work I once had to do in connection with dividing an estate of 27,000 acres of land among a number of heirs. We had to make a survey of the whole tract, and made a stadia survey, showing the contours by different colors; black represented rocky land, red represented land that would need considerable work done on it to make it valuable; brown represented ordinary farming land, etc. The acreage of each kind of land was computed and the board of real estate agents went over the whole map, and they were the men who decided how many acres of land each heir got. Then we had to divide up the tract so that every man would have a good frontage on the main highway and good

drainage at the rear. It took about a year to settle the matter; it was quite complicated and very interesting. The courts were not called upon.

In assessing land over a drainage district some such method as this would have to be followed and the plan outlined by Prof. Ashbaugh is along that line. It is a complicated affair in any event, and it would be hard to have any intelligent discussion of this paper in the absence of knowledge of the statutes of the state.

To make my remarks clear I would like to assume a case. The courts will demand that the assessment be equitable; some land in the district may be worthless until drained. When the time comes to levy the assessment the value may be $10 per acre. It might be termed 100 per cent. land. The assessment may amount to $11 per acre, or practical confiscation. Another lot may be valued at $10 per acre and the drainage will only increase the value $5, so there will be a much smaller assessment levied against it. Another lot may be worth $5 and the drainage will make it worth $10 or more. These may be extreme cases, but I have known others to occur nearly as bad. They will only cause trouble, perhaps, when the owners of the worthless land do not own contiguous tracts of better land which permit of an averaging of values.

Prof. Ashbaugh says the statutes of Iowa require a percentage classification and he mentions three factors common to all districts. My supposititious cases must be considered under the first factor, which is thus complicated by a consideration of cash value, as well as the intrinsic need for drainage. Is the land receiving the greatest benefit "as regards changing the character of the land" entitled to a classification of 100 per cent. if such a rating implies an assessment amounting to confiscation?

*H. S. Maddock*—M. W. S. E.—There is a point in connection with the drainage of swamp land not touched upon in this paper; that is, the maintenance of districts after they are constructed. In a great many swamps the sub-soil is sandy and trouble is experienced in keeping the ditches open. If tile drains are put in, the sand is liable to work into the joints. I have had no experience directly along this line, but I understand that in such cases trouble is being experienced by the ditches filling, and I know of a case in Wisconsin where the district was abandoned on that account.

*Mr. McCullough*—In such cases taxes are generally levied on a district by a board of assessors in the ordinary way that taxes are levied. They assess according to the value of the land. The California procedure is to elect a board of commissioners annually and for three years, one-third going out every year. The people elect this board of commissioners and also an assessor and treasurer. The assessor goes around and assesses the property according to value. They make an estimate every year and get the fund then for the maintenance.

*Mr. Maddock*—Have any attempts been made to prevent the sand from working into the tile drains and have they been successful?

*Mr. McCullough*—Numerous experiments have been tried; the best results obtained by me were in the state of Washington. There we abandoned tile drains as they had to be cleaned every second or third year because of the fine material that worked in through the joints. We substituted wooden drains. These wooden drains were practically long boxes without bottoms. They were made in lengths which could be conveniently handled and had tar paper or burlap placed on the side and top joints. They were butted, end to end, and had short braces across the bottom every three or four feet to keep the pressure of the earth from forcing in the sides. The water then rose into the drains entirely from the bottom and, of course, prevented the fine stuff from settling and choking them.

The cost of the wooden drain was about 10 per cent. higher than the tile drain, but the wooden drain would last from 25 to 30 years without giving any trouble. It was seldom that the tile drains remained in three years without having to be taken up.

*Mr. Maddock*—I met a farmer not long ago and he had the same trouble to contend with that I am speaking about. He claimed that he at last succeeded by putting clay over the tile drains. In this way the water could not get in at the joints and it kept the sand out.

*Mr. McCullough*—We had to drain in Washington for alkali. The people would spend large sums of money for irrigation ditches and canals, and in a very few years the land would be rendered useless by the water leaking from the canals and filling the soil. This would bring the alkali to the surface. In the fall when the water was turned off in the irrigation canals, they would continue running for a long time because of the water in the water-soaked earth would then drain off. These ditches were then acting as irrigation ditches in irrigation season and as drainage ditches the rest of the year.

On one tract of land they got from one and a quarter to one and a half tons of hops per acre. Within three years after the new ditch was put in the land was so water-logged and so covered with alkali that they did not get one-half ton of hops per acre. The owner contemplated a damage suit against the irrigation company. I put in a system of drainage, however, and since then the land is yielding as well as ever.

In an alkali country the material that goes into the drain is very fine, and as the grade is light the velocity is not sufficient to keep the tile drains clear. Where tiling has not proved satisfactory and open ditches were tried, this same material would coat the sides of the ditches so that after a while they did not act well. When the sides were scraped the land would again drain. An open ditch, however, is not always desirable, but is better for such a country than tile drains of the ordinary kind.

At one place we had some special drains made that were square in shape and one corner was cut off. They were laid with this corner at the bottom and the joints were closed so that water could enter only from the bottom. They were put in about four years ago and have given good satisfactin, but are very costly.

I would recommend wood in preference to tile in localities where the water level will never fall below the tops of the drains, so that they may be always moist. In some districts, however, the water level will of its own accord, or because of some other drainage channel, go considerably below the drains. There, of course, these wooden drains will not last very long. The conditions in an irrigated country are hard. About the 15th of April they turn the water into the ditches and it is turned off about the 15th of Sepember. In some sections of the country on the 15th of April you will have to dig six or seven feet before the earth begins to get moist. By the 15th of September the country is so full of water that a man sometimes will leave a wagon in the middle of a field until the following January, when he can get it out without bogging. In draining for hops it is necessary to have the drains at a depth of at least five feet, because hops cannot be allowed to get too wet.

*Chas. B. Burdick*—M. W. S. E.—I have been quite interested in this paper by Prof. Ashbaugh. It takes up a question that it is very difficult to decide equitably to all parties concerned. It is one that comes up not only in drainage, but in municipal improvements as well.

In regard to the mathematical solution of problems of this kind, the laws of the various states and the courts so far as I know do not often concern themselves with the method arrived at in bringing about the result. They are usually only interested in whether or not an equitable result is brought about. And engineers who have had experience along this line have said it is a pretty good plan not to tell what method was used in getting results.

I was particularly interested in that portion of the paper which had to do with assessment on such property as highways and railroads. I know of one case where a railroad passing through a reclamation project will probably be benefited to the extent of several hundred thousand dollars, and it is quite an interesting problem to ascertain just what this railroad ought to pay toward this reclamation project. I understand the railroad is willing to give quite liberally toward the construction of the district.

During the past fall I had the good fortune to be associated with Prof. Mead of this society in the reclamation of some low lands in British Columbia, and the society might be interested to know what they are doing in that country and about what it has cost. In connection with this work I had occasion to look up work previously done there and I came across a table of the cost of ten or a dozen districts on the Frazer River, which might perhaps prove of interest.

COST AND ACREAGE OF DIKING DISTRICTS IN BRITISH COLUMBIA.

(*From report of F. J. L. Tytler, C. E.*)

| *Districts.* | *Acres.* | *Cost per acre.* |
|---|---|---|
| Pitt Meadows | 2,500 | $ 2.00 |
| Coqutlam and Wilson | 3,690 | 5.45 |
| Maple Ridge | 8,600 | 2.33 |
| Johnston Island | 1,300 | 22.20 |
| Motsqui | 10,000 | 3.81 |
| Dewdney | 5,350 | 12.00 |
| Nicomen | 5,600 | 27.10 |
| Agassiz | 5,500 | 6.85 |
| Chitliwack | 22,000 | 10.00 |

I would say that all the improvements of this character on the Frazer River are brought about by reason of floods.

CLOSURE.

*Prof. L. E. Ashbaugh* (by letter)—Since the preparation of the paper on "The Assessment of Drainage Districts," attention has been called to the decision of the Supreme Court of the United States, affirming the Illinois decision in the case of the C., B. & Q. Ry. Co. vs. Commissioners of Drainage District No. 1, Bristol Twp., Kendall Co., Ill. (212 Ill. 103). This decision is of great interest in dealing with award of damages to a railway company on account of a new bridge which may be required to cross a drainage improvement along a natural waterway. If the statutes of other states are not already so framed as to take advantage of this decision, it is probable that proper amendments will soon be made.

The following quotations taken from an interesting context may serve to give the gist of the matter:

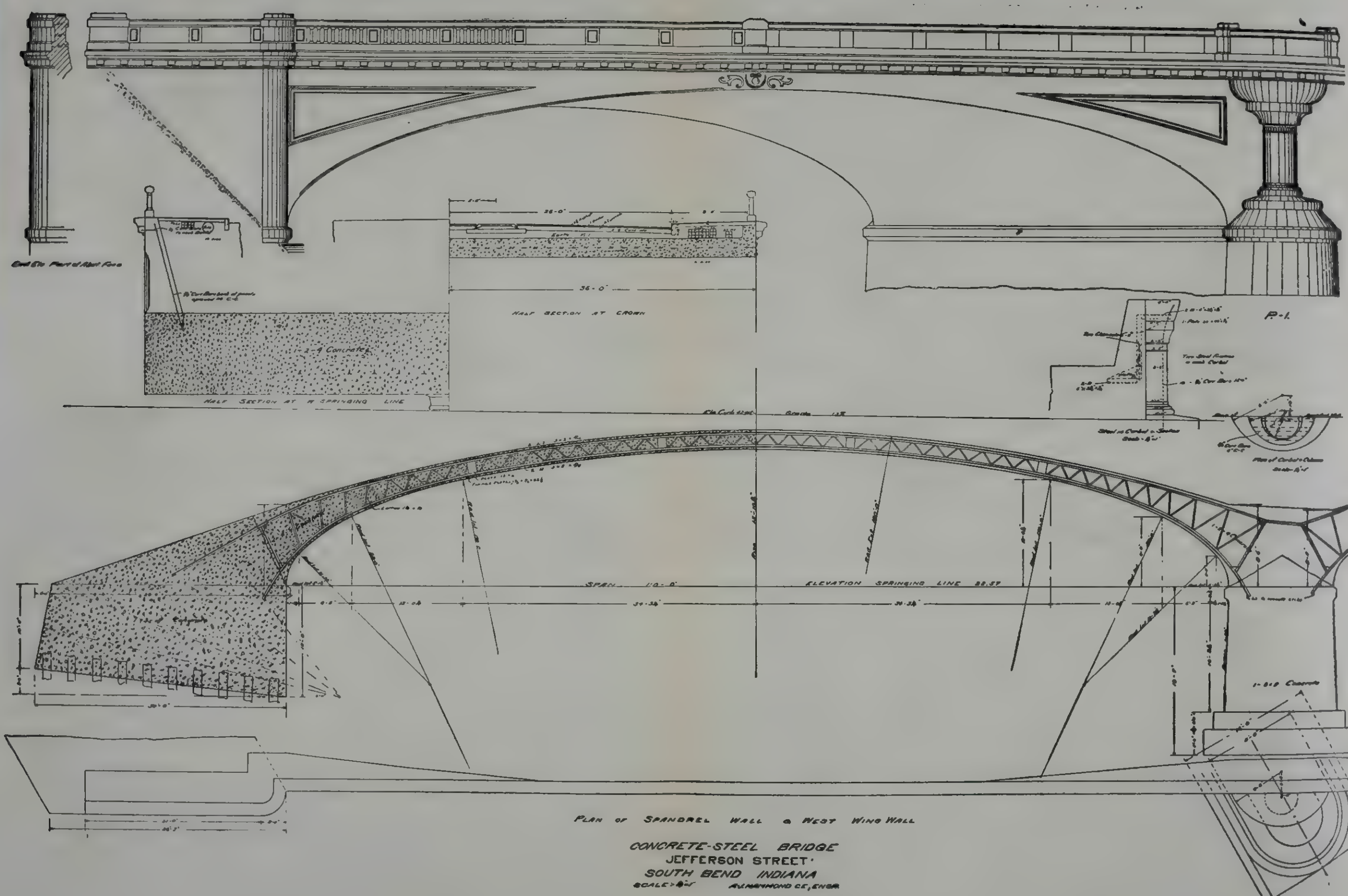
"When the railway company laid the foundations of its bridge in Rob Roy Creek it did so subject to the rights of the public in the use of that watercourse, and also subject to the possibility that new circumstances and future public necessities might, in the judgment of the State, reasonably require a material change in the methods used in crossing the creek with cars. It may be—and we take it to be true—that the opening under the bridge as originally constructed was sufficient to pass all the water then or now flowing through the creek. But the duty of the company, implied in law, was to maintain an opening under the bridge that would be adequate and effectual for such an increase in the volume of water as might result from lawful, reasonable regulations established by appropriate public authority from time to time for the drainage of lands on either side of the creek."

"The great weight of authority is, that where there is a natural waterway, or where a highway already exists and is crossed by a railroad company under its general license to build a railroad, and

without any specific grant by the legislative authority to obstruct the highway or waterway, the railroad company is bound to make and keep its crossing, at its own expense, in such condition as shall meet all the reasonable requirements of the public as the changed conditions and increased use may demand."

"The duty of a railroad to restore a stream or highway which is crossed by the line of its road is a continuing duty; and if, by the increase of population or other causes, the crossing becomes inadequate to meet the new and altered conditions of the country, it is the duty of the railroad to make such alterations as will meet the present needs of the public."

"The duty of the company will end when it removes the obstructions which it has placed in the way of enlarging, deepening and widening of the channel. It follows, upon principles of justice, that while the expense attendant upon the removal of the present bridge and culvert and the timbers and stones placed by the company in the creek, as well as the expense of the erection of any new bridge which the company may elect to construct in order to conform to the plan of the Commissioners, should be borne by the railway company, the expense attendant merely upon the removal of soil in order to enlarge, deepen and widen the channel must be borne by the District."



P-1.
HALF SECTION AT CROWN
HALF SECTION AT SPRINGING LINE
1-2-4 Concrete
SPAN 110-0"
ELEVATION SPRINGING LINE
1-3-6 Concrete
PLAN OF SPANDREL WALL & WEST WING WALL
CONCRETE-STEEL BRIDGE
JEFFERSON STREET
SOUTH BEND INDIANA

## JEFFERSON STREET BRIDGE, SOUTH BEND, INDIANA

A. J. Hammond, Consulting Engineer.

*Presented June 13, 1906.*

The city of South Bend is located in the extreme northern portion of Indiana, on the St. Joseph river at the point where the river abruptly changes its westerly course and flows north to Lake Michigan, and this freak of nature gave the city its name. Our local geologists tell us that the original course of the river was westward through the Kankakee Valley to the Mississippi, but this plan was changed by subsequent glacial action.

The city of South Bend, now some three-quarters of a century old, was built on both sides of the river, which was early spanned by pile trestle bridges. Some twenty years ago Whipple truss iron bridges replaced the old trestles, and these in turn are now being replaced by plate girder and concrete-steel arch bridges. The old steel bridges are being removed to other sites where their light capacities will not be exceeded.

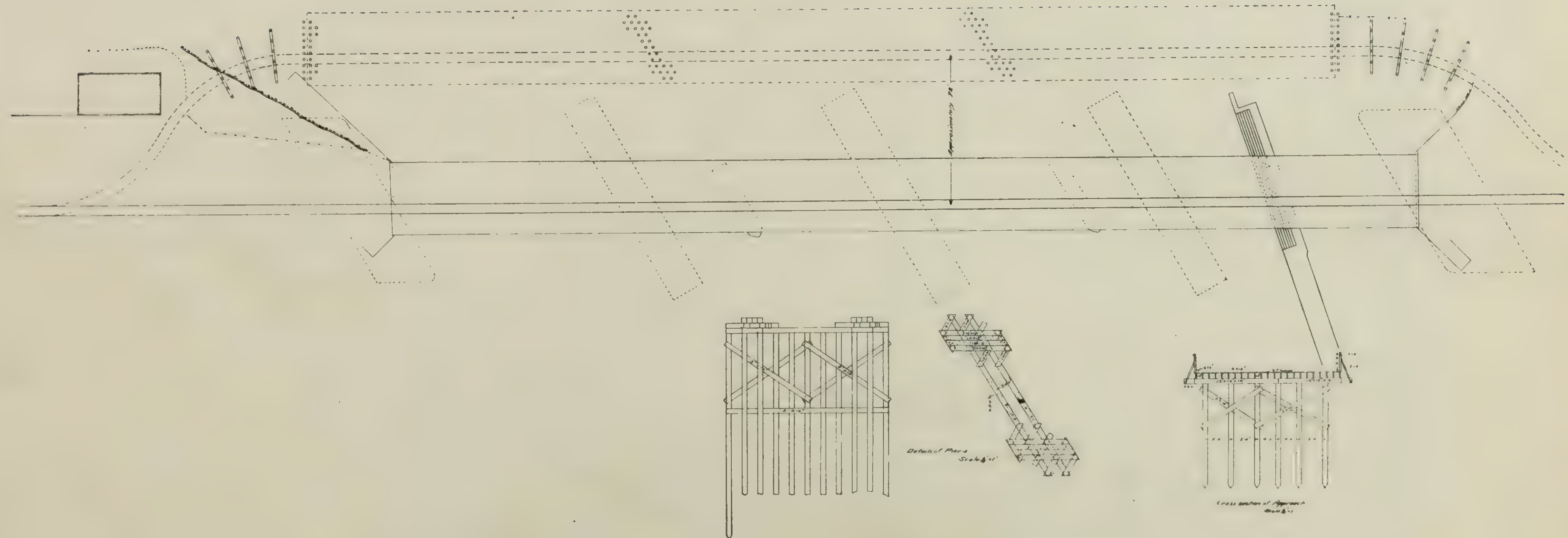
On Jefferson street, at a point some three hundred ft. above the dam in the St. Joseph river, a three span Whipple truss bridge spanned the river, the two piers being on a skew with the axis of the bridge, and the spans being respectively 163 ft., 158 ft., 163 ft., long on pin centers. It was decided to replace this bridge with a 4-span concrete arch, and in order to utilize the river frontage as well as to preserve the water-way, it was decided to keep the length of the new bridge practically the same as the old one.

In order to provide for the traffic during the construction of the new bridge, I submitted plans for the removal of the entire superstructure 72 ft. down stream, in a direction parallel to the current and on a skew with the street axis. The trusses were to be set on nests of piles, and trestles built at each end to connect with the street. These trestles were on reverse curves of about 70 ft. radius, but the rails were bent in place with jim crows, and the track men got quite a smoothly riding curve for so short a radius.

The bridge spans were floated down to the new site on scows, which were afterwards used during the construction of the new bridge, as described in the following pages by Mr. Strehlow. The work of removal was very successfully and quickly accomplished.

At the east end of the bridge site the old bridge extended some 60 ft. beyond the shore line, and a stone wall with steps leading down to the water was one of the features of Howard Park, a beautiful little city park which lies adjacent to the river on the south side of Jefferson street. This river wall is about four feet above the crest of the dam, and during extreme high water the back

Plan
Showing Temporary Location
of
Jefferson Street Bridge.



water spreads over the wall to a maximum depth of about a foot. The maximum rise in the river is, therefore, about five feet.

No local soundings were taken to determine the nature of the bottom of the river, because numerous soundings had recently been taken near the dam site, which disclosed a bed of blue clay some 35 ft. thick, lying immediately below a few feet of gravel, which constituted the bed of the river. Occasional pockets of quick sand or fine river silt had also been found, so that a pile foundation was determined upon. Some boulders, as a result of the glacial drift, are found in the river, and these interfered, to some extent, with

PIER FOUNDATIONS—COFFERDAM PARTLY REMOVED

the coffer-dams, but, nevertheless, very good coffer-dams were obtained for all foundations.

The new bridge consists of four elliptical arches having a span of 110 ft. each. The distance between the abutment faces is 482 ft., and the total length is 554 ft. The bridge is 72 ft. in width between the spandrel walls, only 10 ft. less than the full width of the street. The sidewalks are also widened at the ends of the bridge, so as to spread within 4 ft. of the width of the street. The roadway proper is 52 ft. wide, with two street car tracks.

A bridge of the Melan type was decided upon, and the specifications were practically standard for this type of structure, the calculations being based on the following conditions:

Dead load, concrete..............Weight of 150 lbs. per cu. ft.
Fill ...........................Weight of 120 lbs. per cu. ft.
Pavement .......................Weight of 150 lbs. per cu. ft.
Live load for roadway and walks..Weight of 150 lbs. per cu. ft.
Concentrated moving load for double tracks....40 ton electric car
Modulus of elasticity of concrete..................1,500,000 lbs.
Modulus of elasticity of steel....................30,000,000 lbs.
Maximum stress on concrete
For compression, exclusive of temperate stresses 500 lbs. per sq. in.
For tension, exclusive of temperature stresses.. 50 lbs. per sq. in.
For shear ................................ 75 lbs. per sq. in.
Maximum stress on steel.................18,000 lbs per sq. in.

The steel must be capable of taking the entire bending moment, and the flange areas must not be less than on one-hundred-and-fiftieth (1-150) part of the total arch at the crown.

The foundation piles were to be driven so as to penetrate not more than three-eighths of an inch under the blow of a hammer weighing 2,240 pounds falling 25 ft. Any hard wood piles which would stand the hammer blow were accepted, provided they were not less than nine inches in diameter at the small end, and twelve inches in diameter at the large end. The piles were spaced 3 ft. apart c. to c., and were allowed to project 2 ft. into the concrete.

The contractor was paid per foot for only the actual number of feet of piles driven, cut off, measured in place, so that it was to his interest to drive the piling to grade for the cut off, so as to lose the minimum of timber.

As the site of the bridge is only about 300 ft. above the dam, and the bed of the river tends to rise from silting, the foundations of the piers were carried only some six feet into the clay, or to a depth of 19 ft. 7 ins. below the springing line, the depth being uniform at the piers, and the abutments being carried into the clay.

In order to have the piers parallel with the current of the river, and to preserve harmonious relations with the streets at the ends, it was necessary to construct the bridge on a skew of 60 degrees, and to use a uniform grade of 1.3 per cent ascending towards the west. The springing line was given a uniform elevation of about mean high water, or two feet below extreme high water, so that the rise in the arches was respectively 15.85 ft., 14.25 ft., 12.5 ft. and 11.0 ft., and because of the grade and the skew, the north spandrel wall shows about 0.54 ft. more face above the crown of the arch than the south side, but as one cannot see both faces of the bridge at the same time, this is not of consequence.

The various lines of the bridge, as shown in the illustration, are pleasing. The ellipse was used for the intrados of the arches, as I believe it very little more difficult to build than a three centered arch, and the curve is more pleasing to the eye, avoiding the abrupt changes in curvature to be seen in some three centered arches. Of course this abruptness is often due to carelessness in making the

change in curvature, or point of tangency, and might be avoided, to some extent, by the use of easement curves. The actual rise of the flat elliptical arch is much less than the apparent rise, and flat elliptical arches have been objected to because the sharp curvature at the ends and the light curvature at the center do not lend themselves to harmonious treatment, presenting too much of a beam effect. This, however, is a matter of taste; some people like the beam effect, although it does not appeal very strongly to me.

The central pier of the three was made larger than the other two, not for the purpose of using it as an abutment pier, although it has

MOVING OLD IRON TRUSS SPANS

had a useful effect in that way, but for its effect in the architectural treatment of the bridge. This pier at the springing line was four feet thicker than the other two, and five-and-a-half feet longer. The noses of the piers at each end were semi-circular.

The abutments projected three feet beyond the face of the spandrel walls of the arches, and the corners were round in harmony with the piers.

A longitudinal view along the facade of the bridge shows a projection beyond the general line of the bridge face of three feet over the abutments, at little more at the smaller piers and still more at

the central pier, so as to break the view from end to end outside the balustrade.

In order to have rest spots on the bridge, or view points outside the traveled way, heavy corbels resting on what were slightly more than half columns, projected over the piers. The variation in grade was taken up entirely in these columns, so as to produce, to some extent, the illusion of no grade on the bridge.

The bridge, as noted, is constructed on the Melan system, properly speaking, according to the patents for reinforcement obtained by Prof. von Emperger, in 1897, which provide for steel ribs fol-

REINFORCED CONCRETE BRIDGE—JEFFERSON ST. SOUTH BEND, IND.

lowing the lines of intrados and extrados, with a lattice connection.

The steel ribs or arches were built up of four 3 in. x 3 in. x 5-16 in. angles, two for each flange with lattice of 1¾ in. x ¼ in. flat bars. The upper and lower chords were carried well into the abutment and pier concrete and anchored transversely by 3 in. x 3 in. x 5-16 in. angles riveted to the ends of the ribs. The steel ribs were spaced 35 in. on centers, and tied together at every third rib by flat bars at top and bottom flanges spaced ten feet apart. The concrete, as afterwards described, was laid in longitudinal sections three ribs wide. These bars were on the line of separation and tied the sections together. The steel ribs were built in three sections and the splices

were field riveted. All steel arches were connected by their top flanges continuously over the piers.

The thickness of concrete arch rings at the crown were 27, 28, 29 and 30 inches respectively, beginning with the arch of greatest rise. The flanges of the steel arch ribs were three inches inside the arch ring.

The maximum loading used in the strain sheet was obtained by placing the 40 ton electric car with a 25 ft. wheel base on the quarter point of the arch ring, and the stresses were obtained graphically by methods developed by Mr. Edwin Thacher for the

JEFFERSON ST. CONCRETE ARCH BRIDGE—SOUTH BEND, IND.

reinforced arch ring. The lines of pressure in the piers and abutments were also determined graphically, the resultant being required to come within the middle third of the bases.

The corbels over the piers were tied into the spandrel walls by built Z bars, two to each pier, spread so the lower leg was anchored into the pier concrete, and corrugated bars were used for tying in and sustaining the corbel. The base column and corbel are also tied together by vertical corrugated bars spaced radially. Vertical bars and reinforcement was also used in the spandrel walls to tie them into the arch concrete.

The concrete used in the work was, as a rule, laid wet, using unwashed pit gravel and Portland cement. The gravel was remarkably clean, and approximated very closely the correct pro-

portions for sand and crushed stone. The concrete was mixed in the proportion of one part Portland cement to eight and one-half parts of gravel, for the piers and abutments, and one part cement to seven and one-half parts gravel, for the spandrel walls, cornice and balustrade and parapet walls. For the arches, the proportions were one to five. All exposed faces were given a mortar face one inch thick deposited with the concrete, the proportions being one part cement to two and one-half parts sand. All the cement was tested, the results of numerous tests averaging as follows, for the cement used: viz. Universal Portland.


REINFORCEMENT OF CONCRETE BRIDGE—MELAN TYPE, SOUTH BEND IND.

Fineness, passing a No. 100 sieve, 98.39%; passing a No. 200 sieve, 78.63%. Tensile tests on neat briquettes, seven days old, developed 550 lbs. and in twenty-eight days 711 lbs. For a mixture of one part cement to three of standard sand the seven days test showed 216 lbs. and at twenty-eight days 359 lbs. tensile strength. The contractor as a rule kept about a thousand barrels on hand, so that ample opportunity was afforded to test the cement.

The concrete in the piers was carried up to the springing line, but a depression was left in the center for the location of the steel ribs and for tying in the next layer of concrete. The piers were then carried up into the forms on a serrated design, making a break at each third rib, so that a longitudinal arch ring three ribs

wide, which could be deposited easily as a day's work from one mixer, was given a right angle bearing over the piers and abutments. In reality, therefore, the arches are made up of a series of arch ribs normal to the face of the pier masonry as laid, and with the line of thrust parallel with the axis of the bridge. These longitudinal ribs were in all cases built complete at one time, requiring, at times, the work to extend well into the night.

The corbels developed quite a warped surface, and required very careful treatment in the design and construction of the forms, and which I think the contractor very successfully executed. I may say, in this connection, that the effective treatment of this moulded work was due largely to the interest the contractor and his engineer in charge took in the work.

As the arch ring was given no projection, the plain face had to be given an effective treatment by some other method, which was effected by a very deep and heavy panel over the haunches, the panel being six inches in depth, and also by a moulded projection at the crown of the arch; the moulds for the laurel and other scrolls were carved out of a single heavy pine board and used for all arches.

The cornice projected fifteen inches with a heavy dentil course below. The cornice, pier corbels and columns and base, base of hand rail and balustrade posts were cast in place in timber forms; the balusters and hand-rail were moulded in cast iron forms; the concrete or mortar for the latter being mixed quite dry, in the proportions of one to two and a half. A groove was left in the top and bottom of the hand rail, so that the mortar dowels on the ends of the balusters tied them in place; similar dowels were used on the hand rail.

The forms for arches and spandrel faces were made of 2 in. dressed lumber, with one inch dressed lumber for the lagging. The centers were required to be framed for a rise of arch greater than the rise shown on the drawings by an amount equal to one eight-hundedth (1-800) part of the span, or about one and three-quarters of an inch. This allowance was for the compression of the centering and deflection of the arch rings. The compression resulting from the dead load of the arch ring and back fill ranged from one-half inch to one and one-quarter inches, and a further deflection of a tenth to fifteen-hundredths of an inch took place on removal of the arch centering..

The tops of all arches were treated to a coat of cement grout and a layer of hot coal tar, as was also the back of the spandrel walls. The drainage over the piers was through two-inch gas pipes, and weep holes were left through the retaining walls at the abutments.

The fill on the bridge was mostly sand and gravel furnished from an excavation in the park near by. The fill was thoroughly soaked and permitted to stand over winter, to be more thoroughly settled,

and then rolled with a 13-ton roller, so we anticipate the back fill to be quite compact, and will be free from serious settlement.

The pavement is of asphalt on a Portland cement concrete foundation, six inches in thickness.

The sidewalks are of cement, having a base four inches thick of one to six concrete, and a top surface of one inch of one and a half to one cement mortar. A nine inch steel channel forms the curb face and curved openings are cut through the web to discharge the street water into the river at the arch crowns.

The space under the walks on the north side of the bridge was used for water and gas mains. An expansion joint was put in the gas main, but no provision was made in the water main. Electric conduits were placed under the south walks.

The electric poles used for lights and also for span wire of the street railway are very heavy, and were furnished by the two companies; as these poles are only about 124 ft. apart and on both sides of the roadway, with a 2,000 c. p. arc light for each pole, it may be readily understood that this will be one of the best lighted bridges in the country.

The exposed face of all concrete below the cornice has been gone over by hand, and the pores filled with grout and rubber with a pine float, so that no body of cement is to be left on the face of the work, and a uniform appearance is thus given to the walls.

The contracts were awarded August, 1904, to Scribner & Heyworth, Mr. J. O. Heyworth, of Chicago, afterwards taking over the work, with O. E. Strehlow in charge. The steel work was furnished by the Wisconsin Bridge & Iron Co.

The contract price of the bridge, exclusive of piling, was $119,000; the piles were driven at an expense of 33c per ft., and this amounts to a total of $9,376.95, making the total cost of the bridge $128,-376.95.

The contract price paid for the removal of the old steel bridge was $7,000.00 of which the Street Railway Company paid a proportion. The total cost of the bridge was, therefore, $135,376.95.

## CONSTRUCTION OF JEFFERSON STREET BRIDGE, SOUTH BEND, INDIANA.

O. E. Strehlow, C. E.

A brief description of the methods employed and of the details of construction of bridge work, which Mr. Hammond has fully described as regards the location, design, etc., together with some additional views, showing temporary and permanent work and plant, are presented herewith by the writer, who was in local charge of this work for the contractor, James O. Heyworth, Chicago.

The first work was to move the three 170 ft. Whipple spans of the old steel bridge down stream to temporary pile piers driven far enough from the old piers to clear the new bridge. The plan de-

cided on and adopted was to float the three spans, one at a time, on two scows, to the temporary piers. The shore end of the east span, which overlapped the bank about 70 feet, was slid over to its new location on four 60-pound rails, the river end floating on the scow. These spans weigh about 125 tons each, and the scows are 20 ft. wide, 70 ft. long and 4 ft. 6 ins. deep. Three longitudinal bulkheads, the two gunwales, and six transverse bulkheads, divided the scow into 28 compartments to reduce the effect of a rush of water in the scows, due to slight unequal loading or other causes, and also to lessen the chance of sinking a scow. The east span was moved over in about three hours, the middle span in about half the time, and the west span was moved in about fifteen minutes. The two barges were used on the work of building the new bridge and on other work later.

A dam about 300 feet below the bridge site, with about 2 feet of flash boards on the crest, backs up the river for three or four miles, and high water raises this pool only four or five feet more. This condition permitted dispensing with a cableway for constructing the new bridge and the unusual width of the bridge made a fixed cableway undesirable. Light trestle work across the river, carrying light tracks, derricks on land and water, and the two scows and a smaller one, proved to be sufficient for carrying on the work that otherwise would have been done by a cableway had one been installed.

The dry excavation of east abutment was done with teams and drag scrapers, about one-half of the material being wasted on the low river bank down stream from the bridge; the remainder was placed in Howard Park at end of the bridge and was graded to conform with the elevation of Jefferson street. This filled area and a portion of the street constituted the storage yard for 4,000 cu. yds. of sand and gravel being stored at one time. A guy derrick with 65 ft. mast and 60 ft. boom was erected on the center line of bridge at the top of the west slope of the east abutment excavation. This derrick which hoisted the remaining excavation and the old masonry of east abutment, also placed the concrete and a large quantity of the stone of the old masonry, in the new abutment. The concrete mixer was a "No. 5 Smith," and discharged directly into the derrick skips. The location of the mixer proved to be the most economical, not only for the work at the east abutment but for the work as a whole. The gravel was conveyed from the storage yard to the mixer in 1½ cu. yd. dump cars, the track having a slight down grade, to the mixer. The tracks leading from mixer to the three piers and west abutment were level and two feet above the springing line.

A part of the west abutment excavation was removed with teams, then by hand (which was wheeled into a coffer-dam for other parties), and the remainder was handled by the derrick which was moved over from the east abutment. This derrick also handled the stone from the west abutment and placed it in the concrete in much the same way as the east abutment. The concrete was conveyed in cars from the mixer on the east bank in 1½ cu. yd. bottom

dump cars which were hoisted bodily with the derrick and swung to any point in the abutment. While waiting for concrete cars, the derrick, which operated quickly, was working to its full capacity placing stone in the concrete. This derrick also removed the levee around the abutment coffer-dam and placed it in the back-fill of the west abutment, using a ¾ yd. "orange peel" bucket.

The coffer-dams, which were single rows of 6-inch, 7-inch, or 8-inch Wakefield sheet-piling, driven through sand and gravel into moderately stiff clay (with isolated pockets of sand) were surrounded with the wet excavated material, which was to a large extent removed with the orange-peel excavator before pumping out the coffer-dam. One illustration shows the coffer-dam pumped out, and another shows one side of the coffer-dam removed. The bucket would not dig the clay, so about five feet of clay was dug by hand and hoisted in skips and dumped outside of the coffer-dam. Two 6-inch Morris centrifugal sand pumps run by two 30 H. P. motors were used to pump out the coffer-dams. The round piles for the foundation were driven by a "swivel" pile driver provided with extension leaders.

A large proportion of the concrete in the arches was conveyed in dump cars or ¾ yd. two wheeled bottom dump steel carts on flat cars, which were hoisted up an inclined track. As there was no hoisting engine available at this time, one of the centrifugal pumps and its motor were set up to take the place of the hoisting engine. The shell, etc., of the pump was removed and a "niggerhead" put on the shaft. A 1-inch Manila rope attached to the concrete car and wrapped on the "niggerhead" gave the man absolute control, to vary the speed of the car up to ten miles per hour.

The centering rested on pile bents parallel to the piers 12 ft. apart on centers. The piles were capped with 4x12 in. 16 ft. timbers, on which the 8x12 in. 16 ft. stringers were blocked with wedges. These stringers supported 2x12 in. 12 ft. joist 12 ins. apart on centers and bridged. The lagging was of inch lumber, 4, 6 and 8 ins. wide dressed on one side and edges beveled. The joists were sawed to the true curve of the arch at the planing mill. The pile bents were well braced with 2x12 in. and 3x12 in. plank. The steel ribs were built by the Wisconsin Bridge & Iron Works, in sections, about 40 ft. long, and were given a coat of milk grout before shipment from the Milwaukee shops. Owing to the ribs being built in long sections, the erection work was reduced to a minimum.

The balustrade, except the piers and base, was molded in cast iron forms, the top rail being generally in sections 8 ft. 4 ins. long.

The brand of cement used was "Universal," furnished by the Illinois Steel Company.

DISCUSSION

*Albert Scheible*—M. W. S. E.—Having been at South Bend while this bridge was being built, I am glad to state that the people there seemed to generally appreciate the combination of the practi-

cal with the unusually artistic which they are getting in this bridge.

As long as I am not personally acquainted with Mr. Hammond, I think I might say it seems characteristic of the engineering work which he is securing for that city.

As a layman in bridge building I would like to ask two questions: One is as to whether the Melan type of construction was called for, or specified, in asking for bids, or whether the specifications merely mentioned the general conditions to be met in a reinforced concrete construction, so that this method was selected as the most economical?

*Mr. Hammond*—The Melan system was called for.

*Mr. Scheible*—The other question is as to whether any observations were made to determine the seriousness of the cracking in the east arch? The reports, which were considerably magnified in the papers (probably for political reasons), stated that some surface cracking was due to a too hasty removing of the under-pinning from the centers of the arches. I do not know whether the deflection of 3½ inches refers to that arch as well as to the other, or whether the cracking was serious enough to warrant any determinations, but it would seem interesting, from an engineering standpoint, to have a case where there really was a difficulty resulting from removing the substructure too early.

*Mr. Hammond*—The forming was removed after two of the arches had been built, and the thrust of the east arch, (which is the flattest arch) was obtained against one abutment and against the other arch and pier, so that the force against the next pier was such as to cause a greater deflection than there should have been. In other words, the resistance of the pier and the second arch was insufficient to hold the load, and it settled much more than it should have done, the deflection being about five inches. That deflection caused some fine cracks in the ring, but those are very fine, and levels were taken continuously on that arch after the forming had been removed, until about a week ago when levels were taken to determine the conditions then. After the forming had been taken out for a short time, they put part of it back up, until the other two arches were completed and the force of the thrust of the entire bridge was brought to bear against the east span. From that time levels have been taken frequently and the entire deflection has been about five inches, and practically all that deflection developed during the period the arch forming was out, or a little afterwards. As soon as the thrust of the other arches came against this, it raised a little. The cracks were of such small nature of to be of no consequence. In fact, it is now very difficult to see any cracks in the bridge. The fact is, the construction was carried on in a way that is a little unusual, the cornice being put on at the same time the arch ring was constructed and the forming used for the spandrel walls, deflected along with the arch ring, and in consequence of that there was a strong deflection in the cornice. The cornice was afterwards removed, and I think you would not notice any trouble from that

score now, so, as far as the strength of the bridge is concerned and permanence, there is no question about that at all.

*L. K. Sherman*—M. W. S. E.—I would like to ask how long the arch centering was left in after the concrete was placed? In other words, how long a setting did the concrete have?

*Mr. Hammond*—The specifications called for the centering to be left in 28 days. Also all the arches were to be in before any arch forms were removed; after the four arches were completed, they were left 28 days and the entire filling was placed on the arches before any centering was removed.

*W. S. Cowles*—M. W. S. E.—I would like to ask what provision, if any, was made for expansion.

*Mr. Hammond*—The bridge has expansion joints over the spring lines and also about one-third of the way across the bridge, and in the spandrel walls and cornice more frequent joints were left.

One thing I may say in regard to the construction of the bridge. The specifications originally called for crushed stone in the arch ring, and the contractor, desiring to avoid shipping any stone, took the matter up with the Board and myself in regard to using gravel. A compromise was effected by a reduction in the contract and gravel was used in place of crushed stone all through the bridge, for the arch rings as well as the foundations.

*Jas. B. Marsh*—M. W. S. E.—I have just come from South Bend and the bridge looks fully as well as the cuts thrown on the screen. It is a very handsome piece of work.

In regard to the gravel concrete, my idea is that gravel is just as good when used as they used it there in the concrete as the crushed stone.

I think they had a great many difficult problems in that bridge, owing to the skew of the bridge and the extreme flatness of the arch. The centering being lowered when only two spans were in would tend to make the pier act as an abutment, taking the horizontal force. As I recall those spans, the pier on the east or north side is something like 42 feet thick, that thickness being required to take the thrust on a span 110 feet long with only 11 feet rise, or one-tenth rise. And the question is, how would a metal bridge have acted under similar circumstances? I think it was the stiff ribs in the Melan type of bridge that saved the spans from any permanent injury. Withal it is a very nice piece of work and a credit to the engineer and contractor.

*Ernest McCullough*—M. W. S. E.—I would like to ask if any royalty was paid for the use of the system. I believe it has been asserted that the patents were knocked out a little while ago.

*Mr. Hammond*—The county paid a royalty to the Concrete-Steel Engineering Company of New York.

*Mr. McCullough*—What was the percentage of reinforced concrete, compared with the area of the steel, in sections?

*Mr. Hammond*—1/150 part.

*Mr. Sherman*—Did you have any trouble, Mr. Hammond, with distortion of the ribs for the skew-arch centers? Some of the ribs of course do not run clear across the span; that is, they break off, as shown in the cut, in front of the bridge. We naturally suppose that in placing concrete at the haunches there has been a horizontal thrust on the ribs, and that it would tend to throw them out.

Did you make any provision to carry that force, or was there no distortion?

*Mr. Hammond*—There was no distortion of that kind.

*Andrews Allen*—M. W. S. E.—In regard to the steel ribs used in this arch, there are certain questions with which I happen to be familiar that may be of interest. The arches were continuous over the piers; that is, the 3x3 angle chords were spliced over the piers for their full value. It was not thought possible to determine in advance with sufficient accuracy the exact location of the rivet holes for these connections, and the splice plates were therefore left blank and drilled in the field to fit the holes in the angles. In the first arches furnished, both the plates and the angles were left blank.

The specifications required the use of Portland cement grout on these arches and we experimented a long time before finding a grout that would stick. We finally used a milk grout, skimmed milk and Portland cement, which served the purpose extremely well. The same grout has been since used by us for the preservation of steel work used in permanent contact with moisture. While we do not advocate it as a paint for general use, it has its value under certain conditions.

*J. H. Warder*—M. W. S. E.—Was that mixture composed of milk and cement only?

*Mr. Allen*—Yes. We seem to have found some engineering use for milk.

*Mr. Warder*—Where did that idea originate, of using milk instead of water?

*Mr. Allen*—Our superintendent, Mr. Coddington, had heard of it and tried it.

*Mr. McCullough*—I would like to ask whether that grout coating is of any permanent value, or whether better results would be obtained by leaving that off, providing the metal was kept reasonably free from rust?

*Mr. Allen*—The difficulty is in keeping the metal free from rust. It is shipped and sometimes stored for weeks and months, and it was not thought best to expose it to the elements without any covering at all. The use of paint would not have answered the purpose because it would not have formed sufficient bond with the concrete.

It may also be of interest to know that while the arch was an ellipse, the curve was figured as a many centered circular arch, ordinates being figured every two feet for both the inside and outside arch.

*Mr. McCullough*—In regard to this question of rust, I made some experiments along that line, and when we coated the rods we left some of them exposed for a while until there was quite a lot of rust on them. These we embedded in mortar and left for eighteen months. On breaking them open we could find no signs of rust at all. Some rods had been polished, and in others, where slight rust had accumulated, we found the adhesion was much better than on the smooth rods.

I understand some extensive experiments were made in Europe to test the matter in the same way, and they found there that a slight amount of rust seemed to be beneficial rather than otherwise. I would like to know whether the grouting does any good or not. Mr. Marsh has probably had as extensive experience in building bridges as any man in this country, and it seems to be his opinion, perhaps as a contractor, that the coating with the grout is not of enough benefit to warrant one going to the expense, and in some cases it is a question whether it is any benefit at all.

*Wm. Seafert*—ASSOC. M. W. S. E.—The influence of rust on steel which is to be covered with Portland cement mortar, was thoroughly discussed by the German Association of Cement Manufacturers at several of their meetings, a committee having been appointed to investigate and report on the matter. The substance of this report and of the discussions following was, that a slight coat of rust without scale increased the adhesion between the cement mortar and the steel, at least 10 per cent. The practice of permitting a slight coat of rust to form on steel to be used in reinforcing concrete is now quite general in Europe.

A clear distinction between concrete and cement mortar must be drawn. The surface of the rusted steel must be covered with a rich cement mortar; ordinary concrete will not answer as a covering. It goes without saying that the steel must be free from scale.

The Krupp Co., of Essen, Germany, are placing a new iron cement on the market similar to Portland cement except in color and strength. It is made of lime and silica and 10 per cent. iron ore mixed in the raw cement material. This is burned the same as Portland cement, the 10 per cent. iron ore displacing 7 per cent. of alumina. The resulting product is of a chocolate color and possesses high compressive and tensile strength.

*Mr. Allen*—I might add in this regard that the form of these arches being composed of angles with a space between, with rivet heads at frequent intervals, and with lacing bars between, is such as to give a very good mechanical bond with the concrete.

*Mr. Cowles*—Is not the adhesion of the concrete to the steel one of the main points in the use of reinforced concrete, the action of the adhesion itself being the main point to be considered?

In regard to rust, I would like to know how must rust is desirable to produce this 10 per cent. increased adhesion. Certainly if the rust were great enough, it would have a bad effect, although I understand that a small amount might not be detrimental.

*Mr. Seafert*—There must be no scale. The cementing property between the metal and the concrete is increased. The cementing property in some sandstones is in proportion to the iron present.

*J. N. Darling*—M. W. S. E.—I would like to ask whether there is any iron added to the Universal Portland cement.

*Mr. Seafert*—There is no iron added, simply the slag. In the furnaces they use an iron ore of known constituents, especially selected, which gives a slag that is used instead of clay. This slag is ground up and a little more limestone added to it before being burned to a clinker.

*Mr. Darling*—I have found iron in all samples I have tested of Universal Portland cement.

*Mr. Allen*—Do you find that in other cements?

*Mr. Darling*—I have not recently tested other cements for iron, and I *thought* that the iron in the Universal cement came simply in the slag used in its manufacture.

*Oscar E. Strehlow*—M. W. S. E. (by letter)—It may be of interest to state that a part of the apparent deflection of the east arch is due to the settlement of the east pier, both having been determined with a level, and referred to a bench mark near the bridge. The pier settled about 0.1 foot and the centering was built about 0.06 foot too low, which, with the compression of the forms, is quite appreciable.

In regard to the comparative widths of pier and abutment, I wish to say that the former is 18½ feet, and the latter 42 feet, as stated by Mr. Marsh. Considering the abutment effect of the first two rows of 26 heavy arch piles (driven to refusal) near the east pier under the adjacent arch, also the excess excavated material washed in against the pier by the high water, and finally the tension developed in the continuous steel ribs, the resultant thrust was resisted by the combined action or resistances mentioned, I doubt that the weight of the adjacent arch or the abutment effect of the center pier was brought to bear very much.

The wedges which Mr. Hammond stated as being replaced, were 12 in. by 18 in. and, owing to their size and positions, it was not possible to drive them sufficiently to secure a bearing of the heavy stringers against the soffit. The wedges remained loose until finally removed, but the precaution taken was not out of order.

## IN MEMORIAM

### Henry Williams Parkhurst.

Henry Williams Parkhurst was born in Boston, Mass., June 25th, 1847, but his early life was spent in Providence, R. I., where his family belonged, being lineal descendants from Roger Williams, of the "Providence Plantation."

He was graduated from Brown University in 1868, and soon after began his professional work in the office of S. B. Cushing, a well-known civil engineer in Providence. After about two years in this office he was engaged on double track work on the Providence & Worcester R. R. In 1871 he was First Assistant Engineer on the construction of the Hannibal bridge over the Mississippi River, Mr. E. L. Corthell being Resident Engineer, and Mr. Ed. D. Mason, Chief Engineer.

In 1873 he was Resident Engineer on the Louisiana (Mo.) bridge over the Mississippi River, with Mr. E. L. Corthell as Chief Engineer. Following this in 1874, Mr. Parkhurst was Locating and Resident Engineer under Mr. Corthell, Chief Engineer, on the Sny Island Levee, which extends 52 miles south from Quincy, Ill., on the east bank of the Mississippi. Following this he was engaged with Mr. Corthell on some work on the Mississippi River jetties at the South Pass.

In 1876 he was Chief Engineer in charge of construction of about 35 miles of the St. Louis, Keokuk & North Western R. R. In 1878 he was Resident Engineer in charge of an addition of 45 miles of the Chicago & Alton R. R. between Mexico, Mo., and Kansas City, and later in the same year was Assistant Engineer, and finally Resident Engineer in charge of the Glasgow bridge across the Missouri River.

From November 1879, to the end of 1880, he was Principal Ass't Engineer on the Plattsmouth Bridge, and from January 1881 to June 1882, he was Principal Ass't Engineer on the Bismark Bridge, and from June 1882 to November 1883 he held a similar position on the Blair Bridge, across the Missouri river, the late Geo. S. Morison being Chief Engineer of those three bridges.

From 1883 to 1887 Mr. Parkhurst was in the employ of Mr. Geo. S. Morison, in charge of various bridges and other work, and in 1883-4 was engaged in the survey of a railroad in Venezuela, which however, was not constructed, owing to that country having granted a concession to a French Company.

In 18885 Mr. Parkhurst was in charge of the foundations of the Omaha bridge, and on December 11th of that year, he met with

a severe accident which resulted in having his left leg amputated below the knee.

Mr. Parkhurst was Resident Engineer in charge of the construction of the Merchant's Bridge over the Mississippi River at St. Louis, Mo., from its beginning in 1889 to its completion in 1890, Mr. Corthell being Chief Engineer and Mr. Morison, Consulting Engineer of that notable structure.

In March 1892 he entered the services of the Illinois Central Railroad Company, as Engineer of Bridges and Buildings, though for a part of this time his title was Engineer of Construction. During these 14 years of work for the Illinois Central R. R. he designed and built the Burnside, Waterloo and Memphis shops, the Stuyvesant docks, elevators, wharves, etc., at New Orleans, and many minor plants. He rebuilt the LaSalle, Dubuque and Tennessee River bridges, completed the New Omaha bridge over the Missouri River, carried out the Track Elevation at Hyde Park and the St. Charles Air Line, the Track Depression and Bulk-head work, etc., on the Lake Front, the Terra Cotta protected bridges being a feature of this work, and much other construction work in Chicago, and throughout the System, in connection with double track work and improvements requiring a high degree of engineering knowledge and skill.

Mr. Parkhurst was one of the most advanced creators of concrete work, having designed and built many modern structures of this kind, ranging from the smallest to the greatest. Among them he designed and constructed some notable concrete bridges, one of the most remarkable of which is the 3-span, 140 ft. elliptical arches, double track bridge over the Big Muddy river, near Carbondale, Ill., (completed 1903), which is universally admired because of the beauty of its lines, the boldness of its conception, and the integrity of the work, it being far in advance of concrete work up to that time.

Mr. Parkhurst became a member of the American Society of Civil Engineers, Sept. 5, 1877, and of the Western Society of Engineers, Jan. 7, 1879. He took an active interest in this society, contributing papers and taking part in the discussions. Also filling various offices and finally was elected President, Jan. 5, 1904.

Mr. Parkhurst met with a severe accident, a fracture of the skull at the station of Windsor Park, Chicago, the morning of Feb. 20, 1906 from the effects of which he passed away on the evening of April 7,

*E. L. Corthell,*
*A. S. Baldwin,*
*H. H. Hadsall*
*Committee.*

## Charles Paine.

The Public Press has recently announced the death of an eminent member of the profession, who for many years was one of the most prominent members of this Society, Charles Paine, who died on the 4th of July at his home in Tenafly, New Jersey. Although many years ago he removed from this part of the country, and after a time relinquished his membership, it is very needful that some grateful remembrance of him should appear in these pages, for Mr. Paine was the founder of this Society under its original name of the Civil Engineers' Club of the Northwest.

He was a man who not only thoroughly enjoyed his work as an Engineer but earnestly desired to bring together for professional and social intercourse as many as possible of those who were engaged in the same pursuits as himself, and so, after conferring with two or three other engineers, he arranged with Col. Roswell B. Mason, at that time one of the most eminent engineers in the West, to issue an invitation to a meeting at the office of the latter. This was responded to by about twenty gentlemen, and the Civil Engineers' Club of the Northwest was organized at this meeting, which was held on the evening of May 25, 1869. At this time Mr. Paine was chief engineer of that portion of the (present) Lake Shore & Michigan Southern Railway extending from Chicago to Cleveland.

Subsequently Mr. Paine was elected President of the Society, serving as such from June 13, 1870, to June 9, 1873. His portrait is one of those of the past presidents that are hung on the walls of the rooms of the Society.

Probably most of our members were unacquainted with Mr. Paine, but those who had the pleasure of knowing him can never forget his genial manners and the kindly courtesy which he always manifested. It may be truthfully said that the Western Society of Engineers is fortunate in owing its origin to one who was eminent not only as an engineer, but as a citizen and as a man among men.

We condense the following particulars from biographical notices published in the New York Post and in the Railroad Gazette:

He was a native of New Hampshire and was born April 25, 1830. After attending the public schools until his fifteenth year he began as a rodman on the Vermont Central, becoming division engineer in charge of construction. Later he served in the same capacity on the Vermont and Canada. He then went West and became chief engineer of the various railroads in Wisconsin. In 1858 he was appointed a superintendent of the Michigan Southern and Northern Indiana, and chief engineer in 1864. In 1872 he became the general superintendent of the Lake Shore & Michigan Southern lines. His services on these two railroads covered 23 years, during which he established an admirable reputation. This resulted in his being induced to become the general manager of the

New York, West Shore & Buffalo, upon which he stayed during the entire period of building. He then spent a year studying railroads in Europe.

Upon his return he was vice-president of the Erie for a year, and then for five years vice-president and general manager of the "Philadelphia Co.," of Pittsburg, engaged in developing the natural gas interests of that region. In 1899 he became general manager of the Panama railroad and left it when the United States government bought it.

He was a past president of the American Society of Civil Engineers, of the Western Society of Engineers, and of the Civil Engineers' Club of Cleveland, as well as a member of the Century Club of New York.

He was a diligent and successful writer upon railroad subjects and some of his articles, reprinted under the title of "Elements of Railroading," have become a classic.

Says the Railroad Gazette editor, from long and intimate acquaintance, "Mr. Paine's character was of a type that is now infrequent. We read of such men in the Bible and in some other books, men who were invulnerable to every form of temptation that can come to a man of position and power. We have such men now; we hope for more of them among corporation officers in the future, for sturdy moral character in a severely tempted man is an accomplishment usually got under stress of public opinion. He was a learned man, with fine literary tastes and capacity for expression; a sound engineer of good judgment; and a safe railroad officer who enforced discipline and inspired loyalty."

So will say every member of this society who had the privilege of knowing Mr. Paine well. He displayed conspicuously the characteristics which constitute the professional ideal of engineers. He was not only an able man, but he was a perfect man; honest, just, kind and courageous. His character and life are an example and should be an inspiration to all men, as well as to engineers.

L. P. Morehouse, Hon. M. W. S. E.

## ABSTRACT OF THE MINUTES OF THE SOCIETY.

### *MINUTES OF REGULAR MEETING, June 6, 1906.*

A regular meeting of the Society (No. 578) was held Wednesday evening, June 6th 1906. It being a very warm evening there was a slim attendance, of less than 20. Mr. Andrews Allen, 2nd Vice President, called the meeting to order about 8:15 p. m.

The paper of the evening, which had been printed and sent out in advance, on "The Assessment of Drainage Districts," by Prof. L. E. Ashbaugh, M. W. S. E., was read by the Secretary, as the author could not be present. The Secretary also read a letter from the author, which contained a further statement as to the legal status of the Railroad properties, and assessments for drainage districts. Discussion was presented by Messrs. McCullough, Maddock, Burdick, and Allen.

The minutes of the meetings of May 2nd and 16th were read and approved. The Secretary reported from the Board of Direction that at its meeting held June 5th the following were elected into memebrship:

| | GRADE. |
|---|---|
| H. Foster Bain, Urbana, Ill. | Active |
| Allan H. Stone, Pawnee, Ill. | Active |
| Wm. E. Miller, Charleston, Ill. | Active |

Also that applications for membership had been received from
Edward B. Waite, Chicago.
Elmer H. Olson, Texico, N. M.
George W. Bunker, Grand Rapids, Mich.
Otis Weeks, Denver, Colo.
Floyd W. Place, Chicago.
Wm. F. Steffens, Bristol, Va.-Tenn.
Geo. M. Chandler, Chicago.
Myron R. Stowell, Chicago.
J. H. Sawyer, Chicago.

The Secretary presented the following letter from Mr. John Ericson, Chairman of the Committee on the establishment of a mural standard of length for the engineers and surveyors of Chiacgo and Cook County:

> "*J. H. Warder, Secretary, Western Society of Engineers,*
> Replying to yours of June 4th, I beg to state that I have received no satisfactory answer from Mr. Foster, of the South Park Board, as to locating the proposed Standard Mural Bench on the Lake Front, which seemed to be our last resort. I consider that we have done our best as regards this matter, and as I can devote no further time to it, I respectfully request that the Committee be discharged, and that a new Committee be appointed."

On motion of Mr. Layfield the Committee was discharged from further duty.

The following communication from Mr. E. E. R. Tratman was read by the Secretary:

> "*Mr. J. H. Warder, Secretary, Western Society of Engineers, Chicago.*
> Dear Sir: Mr. Dabney H. Maury, of Peoria, and Prof. L. P. Breckenridge, of the University of Illinois, with D. E. Bartow, Director of the State Water Survey, and Mr. H. Foster Bain, State Geologist, have called attention to the report that a reduction of $350,000 is to be made in the Geological Survey appropriation bill

at Washington. This would seriously affect the work planned by the Illinois water and geological surveys, which are working in co-operation with the United States Geological Survey.

"The Illinois Society of Surveyors has telegraphed Congressman Graff a request to use his influence against the proposed reductions and Mr. Maury suggests that the Western Society of Engineers should take similar action."

Mr. Maury and others have sent telegrams as follyows:

*"Hon. Joseph V. Graff, House of Representatives, Washington, D. C.*

"Please use your influence against proposed reduction in appropriation for Geological Survey, Sundry Civil Bill. Any reduction would seriously cripple proposed work in this State."

Mr. McCullough offered a resolution that, as there were so few present, the matter be referred to the Board of Direction for considration.

The Secretary made a statement to the effect that it was customary at the regular meeting of the Society in June to offer a resolution to dispense with the meetings of the Society during July and August. Such a resolution was offered by Mr. Grant, which was duly approved. The meeting adjourned about 9:15 p. m.

### *MINUTES OF THE EXTRA MEETING, June 13, 1906.*

An extra meeting of the Society (No. 579) was held Wednesday evening, June 13th, 1906. The meeting was called to order about 8:35 P. M., with Vice President Allen in the Chair, and about 40 members and guests present.

There was no business to be transacted, so the Chairman introduced Mr. A. J. Hammond, City Engineer of South Bend, Indiana, who read his paper on "The Jefferson Street Reinforced Concrete Bridge at South Bend." He was followed by Mr. O. E. Strehlow, M. W. S. E. with his paper on the construction of this bridge. These papers had been printed and sent out in advance. There were some lantern slide illustrations from photographs of the bridge.

Discussion followed from Messrs. Scheible, Sherman, Cowles, Marsh, McCullough, Allen, Warder, Seafert, Darling, and Hammond. The meeting adjourned about 9:45 p. m. J. H. Warder, Secretary.

---

## BOOK REVIEWS.

TYPES AND DETAILS OF BRIDGE CONSTRUCTION, Part II. PLATE GIRDERS. By Frank W. Skinner, M. Am. Soc. C. E., New York, 1906, McGraw Pub. Co. Cloth, Octavo size. Price, $4.00 net.

This is a volume of 412 pages and many illustrations dealing entirely with plate girder bridges for railroads and highways. The first 48 pages cover briefly quite general remarks on calculations, specifications, plans and the construction of this class of bridges; the remaining pages, except the last 35, contain numerous short descriptions and illustrations of the various details of a large number of plate girder bridges as actually constructed. The last few pages contain short contributed chapters by Engineers, covering very briefly and in general terms, various questions of the design of plate girder bridges.

In the Preface the Author says the book is intended to present "the development of advance practice and its principal details, to illustrate structures adapted to different conditions, to show the progress from primitive and obsolete construction to the most recent designs in accordance with latest requirements and improved manufacturing facilities, and to record interesting, important, and typical examples" of plate girder bridges for

railroads and highways; this statement must not be construed too literally, for while many of the illustrations are certainly of "primitive and obsolete" designs, the book does not deal with the history of plate girder bridge construction.

The Author further says "the examples presented have been selected because of their interest, and not necessarily because they are approved as models; and particular structures described may or may not be considered as in accordance with good practice." And, "Still other examples of curious or absurd girders show the ingenuity or ignorance of the builder." All of these examples are bunched together without comment or criticism, and it is left for the reader to discriminate between them. This made the compilation of the book a comparatively easy task, but in the writer's opinion resulted in a book of little real value.

On the title page it is stated that the book is for "Students, Instructors, Designers, Engineers, Architects, Officials, Builders and Contractors." As only experieiced Designers and Engineers could be expected to discriminate between the comparatively few meritorious designs illustrated and the many others of indifferent quality or positively bad, it would appear that the book is not one which ought to be used by the other classes mentioned.

If the Author had freely criticised the designs, comparing them with each other and pointing out the merits and defects, he could have made a valuable book for the several classes he claims to have written it for, and have done a real service for technical literature.

Very little of the contents of the book is up to date information, although the Title page bears the date 1906. In fact, as the Author says in the Preface, "Many of the descriptions and drawings are revised or reprinted from those written by the Author and published within the last fifteen years in the 'Engineering Record.'" Fifteen years is harking back a long ways in steel bridge construction. Rarely are the dates of the designs shown, and the only data as to the weight of girder spans, aside from the weights of a very few of the designs illustrated and scattered here and there throughout the book, is in a short paragraph at the head of "Chapter IV" abstracted from a paper printed as long ago as 1894.

The Publishers have done their work well. The book is well printed and profusely illustrated. C. F. L.

Electric Transmission of Water Power, by Alton D. Adams, A. M. McGraw Publishing Co., New York. Full Cloth, 6 by 9 inches. 335 pages. Price $3.00 net.

The first chapter treats of the distribution of water power developments throughout North America and includes a table of the principal plants now in operation, giving the length of transmission system, capacity of plant and population served. The second chapter treats of the "Utility of water power in elecrical supply" in which the author deals with the problem of first cost and fixed charges of water power developments. To bring out real conditions relative to cost and fixed charges, detailed facts concerning several plants are given and are no doubt of greater value than general statements.

The transmission system is then discussed together with the advantages of A. C. and D. C. distribution. This naturally involves the physical limits of transmission which is taken up on a later chapter.

The remaining chapters are devoted to the design of water power stations and the electric equipment thereof together with fourteen chapters on details of the transmission circuit.

The contents of the book is systematically arranged, it is profusely illustrated with photograpic cuts of existing plants and maps, and contains many valuable tables. G. F. M.

HIGH-TENSION POWER TRANSMISSION; A series of papers and discussions presented at the International Electrical Congress in St. Louis, 1904. McGraw Publishing Co., New York City. Full Cloth, 6 inches by 9 inches. Price $2.50 net.

This is the second volume of papers presented on the above subject and is "intended to present in convenient form the state of the art of electrical power transmission as set forth in the International Electrical Congress of 1904."

The papers are of particular importance from the fact that they present modern practice in Electrical long distance transmission engineering, although it will be noted from the discussions that considerable difference of opinion exists relative to some phases of this subject. This, however, adds to the general value of the papers.

The following is a brief summary of the contents:

Electric Power Transmission, by Charles F. Scott. This is principally historical and treats of the rapid progress of long distance transmission engineering in America.

The High-Tension Transformer in Long Distance Power Transmission, by John L. Peck. The paper deals with the development of high potential transformers and their mechanical and electrical design. It is partly historical but contains much information on the present stage of transformer design and use.

Notes on Experiments with Transformers for very high potentials, by Prof. Harold B. Smith. Deals principally with the design of several special transformers for producting very high potentials,—from 100,000 volts to 500,000 volts.

High Potential, Long Distance Transmission and Control, by F. G. Baum. Mr. Baum is transmission engineer for the largest system of electrical long distance transmission in the world, which comprises 700 miles of continuously operated line at 50,000 volts and various other lines at voltages ranging from 5,000 to 40,000. The total available amount of power on the system is 43,650 K. W. The paper deals with simple methods of line calculation and means of controlling the power at high voltages. A large part of the discussion, which followed the reading of the paper, was on the use of lightning arresters, and brought out the fact that none other than the simple horn arresters are used on these lines. The author believes that the line insulator is the weak point in long distance, high voltage, transmission, and as soon as a proper insulator can be designed, transmission of power at 100,000 volts or over will be a simple matter.

American Practice in High-Tension line Construction and Operation, by Dr. F. A. C. Perrine. The author points out the tendency toward standard design of the various systems of transmission and the details entering into their construction.

Spark Distances Corresponding to Different Voltages: By H. W. Fisher. Describes a series of experiments on sparking distances with the object of showing the magnitude of errors that may arise from the use of ordinary needle points.

The use of Aluminum as an Electrical Conductor, by H. W. Buck Conductors for Long Spans, by Francis O. Blackwell. This paper, in conjunction with the preceding, comprises an exhaustive treatise on Electrical Conductors for long distance transmission systems. The facts set forth in these two papers have been derived from numerous tests and experiments that must have taken much time and patience.

High-Tension Insulators, by V. G. Converse. A paper on the various types of insulators used for long distance transmission with a discussion on the requirements of insulators for high tension work.

The Construction and Insulation of Tigh-Tension Transmission lines, by M. H. Gerry, Jr. Describes American Practice in detail, design and construction of high-tension transmission lines including the design of insulator.

Some Difficulties in High-Tension Transmission and Methods of Mitigating them, by J. F. Kelly and A. C. Bunker. The experience of two practical operating engineers.

Pioneer Work on the Telluride Power Company, by P. N. Nunn.

Bay Counties Power Company's Transmission System, by L. M. Hancock. A description of the above transmission system together with an outline of the working organization.

Some Practical Experiences in the Operation of many Power Plants in Parallel, by R. F. Hayward.

Maximum Distance to which Power Can Be Economically Transmitted, by Ralph D. Mershon. A mathematical treatment of this subject.

Some elements in the design of High-Tension Insulation. By Prof. Harris J. Ryan.

Insulating Materials in High-Tension Cables; By E. Jona

The discussion of each paper by prominent engineers together with the context makes this book valuable to the engineering fraternity.

G. F. M.

PRACTICAL TESTING OF DYNAMOS AND MOTORS. Charles F. Smith. Second and enlarged edition. Manchester, England. Scientific Publishing Co. Price 5 shillings net. 8½ by 5½ inches. 306 pages and index. 108 illustrations and diagrams.

The Book is intended to serve as an elementary introduction to the study of the testing of continuous current dynamo machinery. It is intended to be of value to students, assistants in testing rooms, and those who are only slightly acquainted with electrical work but wish to check the performance of machines.

The use of higher mathematics is avoided. Very little actual data on commercial machines is given. General methods of testing for comparing the characteristics of machines are given. An idea of the relative commercial value of a machine can not be obtained by performing the tests as described as from the information given. Either a previous knowledge of what the characteristics should be is necessary or a considerable number of tests must be made on different machines.

The connections, readings to be taken and method of recording results are given. An idea of the magnitude of the forces, currents, etc.. to be encountered and the apparatus required to safely handle them is not given. The experimenter must either have other sources of information or he will learn by sad experience.

The methods and apparatus suggested are more suitable for a laboratory than for a commercial testing room. Many of the tests described are of little commercial importance and the results are usually obtained in other more simple ways.

The most important characteristics:

Commutation--heating—efficiency—excellence of mechanical running—durability of mechanical parts, including commutator—and permanence of insulation—are either not considered or not sufficiently emphasized.

The conversions from temperature rise, degrees centigrade to degrees Fahrenheit given in page 246 are not correct. 32° F should be subtracted from the values given to make up this difference in the zero points of the two systems.

In conclusion:—The book is of value to the student but could be greatly improved for use in industrial establishments. W. J. W. Jr.

CITY ROADS AND PAVEMENTS, suited to cities of moderate size, by William Pierson Judson, M. Am. Soc. C. E., M. Inst. C. E., M. Am. Soc. Mun. Imp. Third edition revised, 6 by 9 ins 197 p. and over 60 illustrations, including many half tones. The Engineering News, Publisher, New York. Cloth bound, price $2.00 net.

Originally written as a report to the officials of a moderate sized city,

this work has been added to and revised until it is now a standard upon the subjects embraced in the title.

It is up to date and can be safely recommended as perhaps the best book a city engineer can give the Councilman to read. It should be read by all paving Committees. Your reviewer can only criticize the section on concrete. So many experiments have been made on sand containing loam and clay that the remarks about clean sand, being an essential seem somewhat out of date. In revising for the third edition the author should have qualified his statements and referred to later experiments, giving results the opposite from his own. In a book intended for non-technical men it is desirable to be a little full in explanations.

On page 50 a concrete mixer is described, that had a short life some years ago. It is not now in the market. There are several machines on the market which are slowly being introduced for mixing concrete, for street paving foundations, but unfortunately these are not shown in this book.

Aside from the criticisms above noted, which do not lessen its value, the book deserves high praise, because of its wealth of information and compact presentation of facts of value. E. McC.

The Corrosion and Protection of Metals:—Preservation of Engineering Structures, by A. Humboldt Sexton, F. I. C. & F. C. S. The Scientific Publishing Co. Manchester, Eng. Red cloth, 7½ by 5 inches, 147 pages, including index, price 5 shillings net.

Though there is some trite and common place matter in this handy little book that can be excused for what there is that is so excellent. Chapter I treats of the rusting of iron and steel, while Chapter II takes up the subject of protection of iron and steel from atmospheric corrosion, which may be by coating with some other metal, like zinc (which has its limitations,) or by applying a surface coating, of that varied and multiform compound, commonly known as paint. Other metals, as lead, zinc, copper etc. are considered by the author in the aspect of thin corrosion under atmospheric influences.

Chapters IV and V relate to the corrosion of metals by gases. water and other liquids. This is of interest in connection with steam-boilers, furnaces and boiler-tubes, and of pipes for conveyance of water for domestic use. Chapters VI and VII relate to the action of sea water on iron and steel, also of copper and brass. These are of importance, particularly to Naval and Marine engineers.

All in all the book is of decided value to an engineer's library. W.

## TRADE CATALOGUES.

Sullivan Machinery Co., Chicago. Modern Methods of Producing Coal. Part I, Catalogue No. 57, 55 pages, 6 x 9 ins.

This catalogue describes coal mining with special references to two cases:—(1) where machines are substituted for pick mining; (2) where machines are substituted for shooting "from the solid." The illustrations show the specialties of this company as employed in both these phases of coal mining. Sullivan Pick Machines are shown in section and described. The pamphlet also includes a table showing the Bituminous Coal Production in the United States from 1891 to 1904, table showing the use of machines for mining coal during the same period, table of the Heating Values of American Coals, and other tables.

Hanna Engineering Works, Chicago, Ill., Catalogue No. I, Hanna Pneumatic Screen Shaker 24 pages, size 6 x 9 ins.

This pamphlet fully describes various standard shakers, the small and the large tripod shaker, the stationary posts shaker and the swivel post shaker. Many illustrations supplement the descriptions, rendering them clear and plain. A list of foundries using these shakers is appended

Catalogue No. 2; The Hanna Automatic Quick Acting Machinists' Vises, 8 pages, size 6 x 9 ins. Descriptions, illustrations and price lists are given with a number of advantages of these vises over other types.

Catalogue No. 3; The Hanna Riveter, 36 pages, size 6 x 9 ins. This booklet describes and illustrates Hanna Riveters, for use in boiler, bridge, tank, car and ship building as well as all other structural iron and steel construction. Four types are considered,—the hydraulic, the hydro-pneumatic, the pneumatic lever and the pneumatic toggle joint types. Diagrams show the mechanical movements, a double-page plate shows detail parts, and a sectional drawing with numbers furnishes the names of the parts. Tables of sizes and capacities are included. The illustrations are printed on heavy white enamel paper, and the reading matter is on a buff paper, of woven linen finish. The illustrations and the printed matter follow in alternate leaves, making a very neat catalogue.

The James Leffel & Co., Springfield, Ohio, Samson Water Turbine, pamphlet "K," 46 pages, 9 x 6 ins.

This catalogue describes and illustrates a number of types of turbines. Tables show guaranteed powers and speeds of various sizes of turbines, under different head pressures. Views show the turbines as installed in a number of power houses.

Leffel Engines and Boilers, catalogue "O," 52 pages, 9 x 6 ins. Different classes of engines are described in this catalogue, with some detail views. Boilers are also described, showing details of construction. Several tables are given referring to different sizes of engines with boilers on same base. These tables include a large variety of combination of engines and boilers.

B. F. Sturtevant Co., Hyde Park, Mass., Sturtevant Engineering Series, containing bulletins 125, 126, 127, 128, 129, 130, 131, 132, 133 and 135. Cloth filing binder 7½ x 9½ ins.

Bulletin 125 deals with vertical engines of high speed, automatic type. giving illustrations and tables of sizes, dimensions, etc.

Bulletin 126, Gas Boosters, describes this device which is a means of locally increasing the pressure of gas to meet special requirements. Descriptions, table of capacities of various sizes boosters, and some information on the installation of one in connection with street means are included.

Bulletin 127 describes High Pressure Blowers, both horizontal and vertical types, giving a table of high pressure blowers suitable for different requirements in foundry work.

Bulletin 128 describes Economizers, pointing out advantages, and showing construction.

Bulletin 129 briefly discusses Pneumatic Separators and Exhaust Fans. Under standard installation is described the method of handling pulverized material. Under Pneumatic System is described the method employed in handling very fine material.

Catalogue 130, The Sturtevant Economizer, devotes 45 pages to this subject, showing construction and installation and includes tables to aid in selection for various conditions; many other useful tables are given, such as the efficiency of fuels, steam tables, water pressure in ounces per square in., factors of equivalent evaporation and others.

Bulletin 131 presents general notes on horizontal engines.

Bulletin 132 refers to several power houses using economizers.

Bulletin 133 describes Gas Blowers and Exhausters, with a number of views showing them as installed in various power houses.

Catalogue 135 is a descriptive price list of blowers, fans, forges, tuyeres, exhausters, economizers, engines, motors, and other machinery. A. L.

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for June, 1906, we have the pleasure to report the following additions to the library and gifts from donors named:

### MISCELLANEOUS GIFTS

Strobel, C. L., M. W. S. E.. Chicago, "Report to the Aqueduct Commissioners, New York City, by the President, James C. Duane, 1887-95. Cloth bound.

Armour Institute of Technology, Chicago, 14th annual Year Book, 1906-7.

Lewis Institute, Chicago, 10th Annual Register, 1906.

Colorado State College, Fort Collins, Colo., 27th annual Register of the Officers and Students. Pamphlet.

Engineers' Club of Philadelphia, Directory for 1906. Morocco.

New Jersey, State of, Railroad and Canal Reports for 1905. Cloth.

Engineering News Publishing Co., New York, "City Roads and Pavements," third edition. By W. P. Judson.

University of Illinois, Urbana, Ill., three pamphlets.—

"Tests of High-Speed Steels on Cast Iron." Breckenridge and Dirks.

"Engineering Experiment Station of the University of Illinois."

"Tests of Reinforced Concrete Beams—Series of 1905." By Talbot.

New Hampshire College Agricultural Experiment Station—Bulletins Nos. 125 and 126.

Iron Age Publishing Co., New York, 'Iron Age Directory, 1906." Pamphlet.

Colorado State Agricultural College, Ft. Collins, Colo., Catalogue and Prospectus, 1906-7. Pamphlet.

Iowa State Highway Commission, First Annual Report for year ending July 1, 1905.

Poor's Railroad Manual Co., New York, "Poor's Directory of Railway Officials,' February, 1906. Pamphlet.

Metropolitan Water & Sewerage Board, Boston, Annual Report, 1906.

Edward A. Bond, Chairman, Advisory Board of Consulting Engineers, State of New York,—Report to Governor, covering period from March 8, 1904, to Jan. 1, 1906. Pamphlet.

John F. Wallace, M. W. S. E., Chicago, The Panama Canal, Supplemental Statement submitted to U. S. Senate Committee on Inter-oceanic Canals, May 22, 1906. Pamphlet.

W. S. Bates, M. W. S. E., Chicago. "Experimental Researches in Steam Engineering," by Isherwood. 2 vols. cloth.

"Experiments in Aerodynamics," by Langley. Cloth.

Michigan State Board of Health, Lansing, Mich. 32nd annual report of the Secretary, June 30, 1904. Cloth

A. W. Robinson, Montreal, Canada. "Album of photographs of dredging and excavating machines."

Cooper, Theodore, New York, General Specifications for Steel Railroad Bridges and Viaducts, 1906. Pamphlet.

Thomas Publishing Co., New York, "Thomas' Register of American Manufactures, 1905-6." Cloth.

Brunner, John, M. W. S. E., Chicago, "The Railways and the Republic," Index of Proc. Vols. I to X of Engineers Society Western Pa., by J. F. Hudson.

Library, University of Michigan, June, 1906, number of The School Review. Pamphlet.

State of Maine, Dept. of Vital Statistics, 13th annual report on births, marriages, divorces, and deaths in the state of Maine, 1904.

Butler, M. J., Department of Railways and Canals, Dominion of Canada, "Annual Report of Railways and Canals, 1904-5, with maps." "Canal Statistics for the season of navigation, 1904." Pam. "Railway Statistics for year ended June 30, 1905." Pam.

Bixby, Lieut. Col., M. W. S. E., Chicago, two pamphlets,
"Final Report, recent Illinois Waterway Survey, House Document 263, 59th Congress, 1st Session."
"Specifications for concrete superstructure, improving Chicago Harbor." May 26, 1906.

Yeates, W. S., State Geologist, Atlanta, Ga., eleven pamphlets, Bulletins Nos. 1-11 inclusive (1894-1904).
The Paleozoic Group, J. W. Spencer. Pam.

White, James, Geographer, Dept. of Interior, Ottawa, Canada. Standard Topographic Maps of Canada.

A. P. Low, Geological Survey of Canada, Ottawa, Canada, "Mineral Resources." 14 pamphlets.
Annual Geological Reports, 11 vols, 1890 to 1900.
33 Pam's., parts to accompany Annual Reports 1885, 6, 7.

The Lake Torpedo Boat Co., Washington, D. C., "The submarine versus the submersible," by Simon Lake. 1906.

Engineers' Society of Western Pennsylvania, Pittsburg; Membership List, 1906.

David Ross, Sec'y, Bureau of Labor Statistics, Springfield, Ill., 24th annual Coal Report of Illinois Bureau of Labor Statistics, 1905.

P. Blakiston's Son & Co., Philadelphia, Elements of General Chemistry, with Experiments, Prof. J. H. Long. Cloth.

B. F. Sturtevant Co., Boston, Ventilation and Heating. Cloth.

Superintendent of Immigration, Ottawa, Can., Canadian Year Book for 1906.

Scientific Pub. Co., Manchester, Eng., Steam Turbines and Turbo-Com-

Lowell, Mass., Water Board, 33rd Annual report to City Council, 1905.

Mankato, Minn., City Engineer's Annual Report, 1906.

Chicago, South Park Commissioners' Annual Report for 1902, 3, 4 and 5.

Mr. Andrew Bell, C. E., Almonte, Can.—
One book, paper, Annual Report Dept. R. R. and Canals of Canada, 1905.
One book, paper, Report of Minister of Public Works, 1905.
One book, paper, Proc. Ontario Association of Architects, 1905.
One book, cloth, Report of Comsr. Dept. Interior, Dom. Can. on Electro-thermic processes for melting of iron ores and making steel in Europe, 1904.
One Pamphlet, Mines Branch, Dept. Interior, Can. Preliminary Report of Experiments made at "Soo" (Ontario) on Smelting of Canadian iron ores by Electro-thermic process, 1906.

Chas. P. Neill, Commissioner Dept. of Com. and Labor, Bureau of Labor, Washington, D. C., 20th Annual Report Comr. Labor, 1905.

## GOVERNMENT PUBLICATIONS.

U. S. War Department, Bureau of Engineering, Report for the fiscal year ended June 30, 1906.

U. S. Geological Survey, Department of Interior,
- Water Supply and Irrigation Papers, Nos. 153, 165, 166, 168, 169, 171. Six pamphlets.
- Professional Papers, Nos. 45, 47, 49. Three pamphlets.
- Production of abrasive materials in 1905.
- Production of monazite, zircon, gadolinite and tantalum materials in 1905.
- Production of talc and soapstone in 1905.
- Production of precious stones in 1905.
- Production of arsenic in 1905.
- Production of fluorspar and cryolite in 1905.
- Production of asbestos in 1905.
- Production of Zinc in 1905.
- Production of Mineral Waters in 1905.
- Production of salt in 1905.
- Production of phosphate rock in 1905.
- Production of Magnesite in 1905.
- Production of carbon dioxide in 1905.
- Production of slate in 1905.
- Production of quartz and feldspar in 1905.
- Production of quick-silver in 1905.
- Production of peat in U. S.
- Production of gypsum and gypsum products in 1905.

U. S. Department of Commerce and Labor, Bureau of the Census,
- Bulletins Nos. 39, 41, 42, 43, 44; five pamphlets.
- Special Report; Mortality Statistics, 1900 to 1904. Cloth.
- Special Report; Telephone and Telegraphs, 1902. Cloth.

U. S. War Department, Report, Chief of Ordnance, 1905. Cloth.

Library of Congress, Washington, D. C.,
- Want List of Publications of Foreign Societies. Pamphlet.
- Want List of Periodicals and Serials. Pamphlet.
- Select List of Recent Purchases—Science. Pamphlet.
- Classification, Class Q—Science. Pamphlet.
- Select List of Works relating to Employers' Liability. Pam.

U. S. Department of Agriculture, Forest Service,—Grades and amount of lumber sawed from yellow poplar, yellow birch, sugar maple, and beech. By E. A. Braniff, 1906.
- Bulletin No. 168 The State Engineer and his Relation to Irrigation.

## EXCHANGES.

Institution of Mechanical Engineers, Westminster, England,
- Proceedings, October-December, 1905. No. 4. Paper.
- Proceedings, January-February, 1906. No. 1. Paper.
- List of Members, Articles and By-laws, 1906. Paper.

University of Montana, two pamphlets,
- "Bulletin No. 34," and "Eighth Annual Announcement University of Montana Biological Station at Flathead Lake," Bul. No. 35.

Royal Society of New South Wales, Journal and Proceedings for 1904, vol. 38. Paper.

National Fire Protection Association, Chicago, Proceedings of the Tenth Annual Meeting, 1906. Paper.

Connecticut Society of Civil Engineers, New Haven, Conn., Papers and Transactions for 1906, and Proceedings of the 22nd Annual Meeting. Paper.
American Institute of Mining Engineers, New York, Transactions, 1905.
American Society of Mechanical Engineers, New York, Transactions, 1905.
Society of Engineers, London, Transactions 1905, and General Index, 1857-1905.
Purdue University, Lafayette, Ind., Purdue Engineering Review, 1906. Pam.
University of Michigan, Ann Arbor, Mich., Michigan Technic, 1906, Pam.
Institution of Civil Engineers, London, Minutes of Proceedings, v. CLXIII, Part 1, 1905-6. Paper.
Amer. Ry. Engineering and Maintenance of Way Association, Chicago, Bulletins 75 and 76, May and June, 1906. Two pamphlets.
Association of Civil Engineers, Cornell University, Transactions 1905-6.
Boston Society of Civil Engineers, Constitution, By-laws and List of Members, 1906.
Smithsonian Institution, Washington, D. C., five bound volumes, Annual Reports, Boards of Regents, U. S. National Museum, 1886, Part 2; 1897, Part 2; 1898, 1903, 1904.
Junior Institution of Engineers, London, Transactions 1904-5. Cloth.
Chicago Board of Trade, 48th annual report, 1905. Cloth.
American Institute of Electrical Engineers, Vol. XXIV, Trans. Cloth.

## TRADE CATALOGUES.

Hanna Engineering Works, Chicago, Catalogues Nos. 1, 2 and 3—The Hanna Riveter. 1906. Pamphlets.
B. F. Sturtevant Co., Hyde Park, Mass. Sturtevant Engineering Series, Bulletins 125, 126, 127, 128, 129, 130, 131, 132, 133. Pamphlets.
General Electric Co., Schnectady, N. Y., Bulletins of apparatus. Six pamphlets.
E. H. Stroud & Co., Chicago, Crushing, Disintegrating, Pulverizing and Shredding Machinery.

## ADDITIONS TO MEMBERSHIP.

Kermer, Martin T., Active .................................... Aug. 4, 1906
409 E. Superior St., Chicago.
Michaelis, Dr. Wm., Jr., Active ............................ Aug. 2, 1906
1115 Schiller Building, Chicago.
Thorkelson, Prof. H. J. B., Active ........................... Aug. 7, 1906
311 Charter St., Madison, Wis.

## OMITTED FROM THE LIST OF 1906.

Barcroft, Frederick T., C. E., Joy & Barcroft, Archt. & Engr., Detroit, Mich.

## CORRECTED ADDRESSES.

Black, Robert M., not Ralph (Junior).
Crocker, Herbert S., Bridge Engineer, Tramway Co., Denver, Colo.
Dawley, Wm. S., Chf. Engr. Allegheny Impt. Co., Security Bldg., St. Louis,
Dobson, Franklin P., 217 Arizona St., El Paso, Tex.
Holthoff, H. C., Taxco, Guerrero, Mex.
Murr, Lindsley A (Junior) with S. A. L. R. R., Jacksonville, Florida.
Westcott, Oliver J., Structural Engr., 1107 Security Bldg, Chicago.


CARTA DEL ISTMO DE PANAMA
1898.
MAR DE LAS ANTILLAS
OCEANO PACIFICO
ARCHIPIELAGO DE LAS MULATAS
GOLFO DE S. BLAS
LIMITE CON COSTARICA
LIMITE CON EL DEPARTAMENTO DEL CAUCA
DISTRITO DE BOCAS DEL TORO
PROVINCIA DE CHIRIQUI
PROVINCIA DE VERAGUA
PROVINCIA DE COCLE
PROV. DE LOS SANTOS
PROVINCIA DE COLON
PROVINCIA DE PANAMA
LAGUNA DE CHIRIQUI
Isla Escudo de Veragua
GOLFO DULCE
GOLFO DE MONTIJO
GOLFO DE PARITA
GRAN GOLFO DE PANAMA
ARCHIPIELAGO DE LAS PERLAS
GOLFO DE S. MIGUEL
GOLFO DE URABA
ISLA DE COIBA
Isla Cebaco
SANTIAGO
PANAMA
COLON
Chagres
Portobelo
Pta. Burica
Islas Ladrones
Islas Secas
Islas Contreras
Ia. Montuosa
Ia. Jicaron
Ia. Parida

Journal of the

Western Society of Engineers.

VOL. XI. OCTOBER, 1906. NO. 5.

## PANAMA—PAST AND PRESENT.

W. J. KARNER, M. W. S. E..

*Abstract of lecture delivered September 11h, 1906*

Originally Panama was considered as a part of South America and was known as New Granada. In 1819 under General Bolivar, New Granada, Venezuela and Quito (now Ecuador) gained their independence from Spain and were officially constituted the Republic of Columbia. In 1858 the Republic was changed into a confederation of eight states, under the name of "Confederation Granadina," but in 1863 another constitution was adopted under the name "United States of Columbia." One of these states was Panama, which subsequently revolted, to be independent of the others, and constitutes the Republic of Panama. The constitution of the Columbian States remained in force for 22 years, though during that time there were 11 revolutions, an average of one every two years. In 1885 another constitution was adopted which changed the name and title of the country to that of "The Republic of Columbia." Discontent, born partly of the actions of the central government at Bogota, resulted in the separation of Panama from the Sister States, and establishing, November 3rd, 1903, the independent Republic of Panama.

For such rights and privileges on the Isthmus as are controlled in the Canal Zone by the United States, this country paid the new Republic the sum of $10,000,000. The greater portion of this has been invested in good interest bearing securities.

The Republic has a coast line on the Pacific Ocean of about 420 miles, it varies in width from 118 to 27 miles at the narrowest part, and has an area of only 31,570 square miles, which is but a little more than our own Indian Territory and is 4½ per cent. less than the area of the State of Maine. The Isthmus of Panama does not include the whole Republic as shown on the map, but is only the narrow neck of land restricted to the crossing between the cities of Panama on the south and Colon on the north. There are two other narrow crossings within the Republic known as the Isthmus of San Blas and the Isthmus of Darien, which have been surveyed as possible routes for an inter-oceanic canal. The widths of these places are 27 and 32 miles respectively, while the Isthmus of Panama is 31 miles wide.

The population of Panama in 1904 was estimated at 285,000 or about that of Milwaukee. Nearly one-fourth of the Republic is so sparsely settled as to be practically uninhabited. In the interior among the mountains, the inhabitants are principally Indians, of which there are a number of distinct tribes. They are generally civil, and treat visitors courteously, but do not encourage strangers to settle among them. Each tribe has its own local government, and as many of the tribes had practically nothing to do with the movement to establish the new Republic they take very little interest in the general government and public affairs. They simply wish to be let alone.

VIEW OF PANAMA FROM THE BAY; MT. ANCON IN THE REAR

Though a large portion of the Republic is mountainous, from my observations, I believe that on both the Atlantic and Pacific sides, the central plains and foot hills are very rich and fertile. South of the Canal Zone are some extensive savannahs or rolling prairies affording fine pasturage for stock, and also suitable for nearly all branches of farming, though thus far very little has been brought under cultivation.

The laws of the country relating to public lands are somewhat peculiar; all the land within the Republic is owned by the government and by constitutional provision, the title to the land can never pass to any one else. All the land is free and any one may enter upon land that is not actually in cultivation, and cultivate it as long as he occupies the land, and hold it against all comers, the tenure amounting to a lease in perpetuity. There are two excep-

tions to this rule, one being that with all concessions granted by the government, a tract of land is usually given with the concession, such grant being described by metes and bounds. Anyone holding land within these boundaries at the granting of the concession is protected, but no one may enter upon lands within the concession without the consent of the concessionaire. The other exception is that when a holder improves his land by planting "permanent crops," as rubber, cocoanut and cocoa trees the land is not open to public occupancy, even if the planter fails to ocupy it.

In the valleys and mountains along both coasts there is growing timber, valuable for ship and house building, and for fine cabinet work, also dye woods of many varieties. Among these woods is "lignum-vitæ" which has had considerable use as railroad ties, in the construction of the Panama Railroad, and many af these are still in the track and are cheaper at $2.00 each than other and softer woods at one-quarter that price. But the mahogany lumber has the greater demand and is perhaps the most valuable. The mahogany does not grow in groves, but is more isolated and scattering. The trees nearer the large streams and civilization have been all cut off, and it is now necessary to go much further away from the settlements to find good trees. They are sometimes very large and as they are in places that can not be reached by teams, they have to be rolled or hauled by men through the jungle to some water course to be floated to the river or a railroad station for transportation to a seaport. It is often necessary to dam the stream to float the large logs to move them but a short distance at a time. It frequently takes two or three years to get a large mahogany log from the place of its original growth to the hold of the vessel to transport it to market.

As in most tropical countries there are many varieties of snakes in all parts of the Republic and some are said to be quite poisonous. "Culebra" is the Spanish for "reptile" and Culebra hill, the great obstacle to the excavation of the Canal, is supposed to be the home of snakes, but our engineering parties, to my knowledge, have not in this matter been troubled. The underbrush and other tropical growth is so dense, it is necessary to have machete men to cut a path for the engineers, and the snakes may have been driven away by such operations. There are certain insects through the country, as the red-bug and the wood-tick which are "pestiferous peace destroyers" and which are difficult to guard against, yet the native Indian women and children do not seem to be annoyed by these.

At present there are no manufactories nor industries in the Republic operated by local capital; their mineral resources are undeveloped, and there are many square miles of rich and fertile land that are still the hunting ground of wild animals and of wandering Indians. The principal cause for this lack of improvement and development is the frequent political troubles that have racked and devastated the country since the formation of the United


CATHEDRAL AT PANAMA

States of Columbia in 1819. The party feeling was most bitter, and relentless was the persecution of those who differed with the governing party; the people had little time for anything else than fighting, and endeavoring to protect themselves from their political enemies. During these years of strife the Panamanians have been practically a unit against the government of Bogoto; now that Panama is free and independent, if the people will hold together in the future, there is no apparent reason why the Republic of Panama should not be a leader among the Latin-American Republics.

In 1517, or about 25 years after Columbus' discovery of the Western World, the Spaniards built a city called Panama, about 5 miles northeast of the present city. Why that almost inaccessible place should have been selected by its founders, is not known.

There was practically no harbor there, and merchandise and supplies for this city of Old Panama, from the Carribean Sea were taken up the Chagras river to Cruces, and then carried on a stone road to their destination. History represents the old city as much larger than the present Panama, and a place of considerable wealth.

In 1518 the Church and Civil Government were transferred there from Darien, and in 1821 a city charter was granted by the Emperor, Charles V, and soon this city was the seat of Spain's first glory in the Western World, and upon which her empire of the West was founded.

It was here in 1525 that Pizarro and two companions formed a company to conquer Peru, which was accomplished in 1532. From then up to 1546 the city was prosperous because of the commerce crossing the Isthmus between Spain and Peru. After 1546, however, a large part of this trade went by ships around Cape Horn.

Because of the accumulated wealth resulting from this trans-isthmian commerce, Panama was frequently attacked by French and English pirates and in 1571 that historic pirate, Sir Henry Morgan, and his buccaneers, assisted by the Indians (who hated the Spaniards) swept down on the doomed city and literally extinguished it. The spot is now deserted; there are some remains of the buildings, the cathedral tower, fragments of walls, etc., which are over-covered with a dense growth of tropical vegetation,—all that is left of a once wealthy and prosperous city. At the destruction of the old city by the pirates, the stricken and terrified inhabitants fled along the coast to the short peninsula surrounded by steep rocks where they founded the city now known to the world as Panama. It stands on a volcanic plateau, jutting out into the shallow water at the head of the bay. The site was probably selected as being more easily defended by reason of the steep rocks on each side of the peninsula, and with Mount Ancon in the back ground. The new city when built, was strongly fortified and surrounded with strong walls with bastions at the ends of the front wall facing the Pacific. These walls and bastions are now nearly in ruins, but judging from these, in the early days an attack on the city would have been a serious undertaking. In the old part of the city, within the fortification walls, the blocks of two and three storied buildings are nearly solid. Most of them are of rubble masonry with the customary red tiled roofs of Spanish cities; the larger houses are built around a court or patio as in Mexico. For two hundred years or more the present city of Panama was one of considerable wealth and importance, on account of the wealth and treasure coming up from Peru, and carried

through the city in crossing the Isthmus. There were no graded roads nor wheeled vehicles, but everything was carried on muleback or man-back, over the narrow trail and tangled path between Panama on the Pacific Ocean and Portcbello on the Atlantic side. This applied to the treasures of Peru on their way to Spain and the luxuries of Spain on their way to Peru. Only merchandise

A STREET IN PANAMA

of high rating could be so transported, valued not by the ton, but by the pound or the ounce. Though the tonnage was but moderate, probably no other overland commerce in history has been worth so much per pound. History tells us that in some years the transfer of bullion for the King's Fifths amounted to $24,000,000 a year. This commerce with the movement of adventurers and emigrants bound for Peru, made Panama one of the most prominent landing points on the Pacific Coast, but during the past fifty years the city has had a checkered career; twice within that time it has been nearly wiped off the earth by fire, the last time in June 1894, which, with the suspension of work on the Canal on the part of the French

Company, nearly completed the ruin of Panama. In 1901 there was an estimated population of 20,000 and the partial census taken by the Canal Sanitary Department in 1904 showed there had been very little if any increase since that time.

In the older parts of the city the streets are narrow, from nine to fourteen feet, with sidewalks only two and one-half or three feet wide. There, as in European cities, vehicles and pedestrians turn to the left instead of the right as with us, so there was fre-

THE BISHOP'S PALACE

quent narrow escapes on those narrow walks from collisions with boys carrying trays of cakes or with women with large baskets of produce or laundry work, balanced on their heads.

Within the old line of fortifications and near the business centers of the city are three small "plazas," or parks, each covering about a block. Under the old management, the gardening in these parks was somewhat on the jungle plan, the corners and spaces not devoted to walks being filled with a profusion of tropical trees and

plants, in some cases almost too dense to penetrate. But the Sanitary Department declared war on these mosquito incubators and removed most of the shrubbery and built concrete walks.

On the north side of the Cathedral Plaza, occupying half a block front, is the Bishop's palace, a large three storied building of the Renaissance style, its facade being adorned by some fine mouldings. It is probably the finest building, architecturally, in the city. The Bishop occupies the second and third floors, but the major portion of the ground floor is occupied by the Panama Lottery Company. Facing the Plaza on the west side and cvering nearly the entire block is the Cathedral, the largest church in the Republic,

ARCH IN THE RUINS OF THE OLD CHURCH OF SAN DOMINGO

and probably the largest in Central America. It was built about 1760, and is typically Spanish in its architecture, but it is not particularly attractive, notwithstanding its grand size. Owing to the poverty of the people, impoverished as they have been by the frequent revolutions, the Cathedral has had a hard struggle for existence, and has had to part with most of the silver and valuables that once filled its Treasury. On the south side of the Plaza are two buildings which cover that block; one of these is the Munici-

pal Palace, or City Hall, a building with considerable height, with three tiers of galleries in the front; on the opposite side of a narrow street, and also fronting the Plaza is the building formerly occupied by the Inter-Oceanic Canal Company, but now owned by the United States, and for two years was used by the Isthmian Canal Commission for its headquarters and offices. It is the largest and most substantial commercial building in the city. Now most of the various departments of the Commission have been moved to new office buildings in the Zone, along the line of the Canal.

Revolutions and fires have left marks here in ruined buildings. One of these is of particular interest, the remains of the church of San Domingo; no one seems to know exactly how old the church is, but tradition says it was built about two hundred years ago, and that the night before it was to be consecrated it was destroyed by fire, and it has never been rebuilt. It stands now as one of the wonders of the world, as it contains a flat arch made of brick and without a keystone. This arch has a span of about fifty feet, and with a depth of eighteen inches or two feet at either side; it is about thirty feet from the ground, is absolutely unsupported, a small brick link between two walls, and has hung there for probably two centuries. This fact has been used by the Panama people as an argument that there is little fear of damage to the Canal and auxiliary works from earthquakes.

In 1904 and even now the population of the city of Panama is very cosmopolitan in its character. When the Sanitary Department took its census it was estimated that about one-third of the people were Jamaican and Martinique negroes, and the Chinese out-number the Americans more than two to one. Except the Americans, nearly all of the three classes mentioned were "left overs" from the suspension of Canal work by the old Frnech Company. Most of the influential and prominent business men are of Spanish descent. A few claim to be pure Castilian, and some of the prominent families can trace their ancestry back four hundred years and direct to royalty. It is an exception to find a prominent man who does not speak Spanish, French and English. It is something of a surprise to find that English is so generally spoken on the Isthmus. The children of the prominent families are generally educated in the United States, which explains the general use of the English language.

On November 3rd, 1904, the infant Republic of Panama celebrated the first anniversary of its natal day, according to the manners and customs of other civilized nations. Contrasting their first year of peace and prosperity as a Republic, free of any national debt, and with signs of continued prosperity and future progress, to the many years of misrule and revolutions, bringing devastation and misery to the country, one day was not sufficient to do justice to the occasion and give full vent to their enthusiasm, and so four days were given up to pleasure and patriotism.

In the Canal hospital at Ancon the French Company left a grand monument to their good judgment and forethought. The hospital was composed of a group of about thirty detached buildings situated in a beautiful park of forty-five acres, lying on the northern slope and at the foot of Ancon hill, a picturesque sugar loaf hill with an elevation of about five hundred feet above sea level. This hill and the hospital grounds are just beyond the city limits and within the Canal Zone and are practically owned by the United

THE CANAL HOSPITAL AT PANAMA

States. As the larger part of the hospital park is on the slope of the hill, most of the buildings are located on terraces, thus affording extensive and beautiful views of the tropical area between Ancon hill and the mountains of the "divide" as well as of Panama Bay and the Pacific Ocean, with many islands near the outer line of the bay. The roads winding around and leading to these various terraces are all macadamized and had borders of rare plants and shrubs. The slopes of the terraces were also covered with flowers and plants but most of these have since been removed by orders of the Medical and Sanitary Director, to prevent the propagation of mosquitos which are regarded as the principal agent for the introduction and spread of yellow and malarial fevers.

In the Park in Colon, on the sea side of the Washington hotel, is a round shaft of polished granite supported by a triangular

pedestal, a monument to the three builders of the Panama Railroad. These were Wm. H. Aspinwall, John L. Stephens and Harry Chauncey. On each side of the pedestal is a profile bas-relief portrait of one of these three men, as brave and enterprising as the world ever knew. The work they undertook was at that time one of the greatest magnitude, and a trip over the Railroad

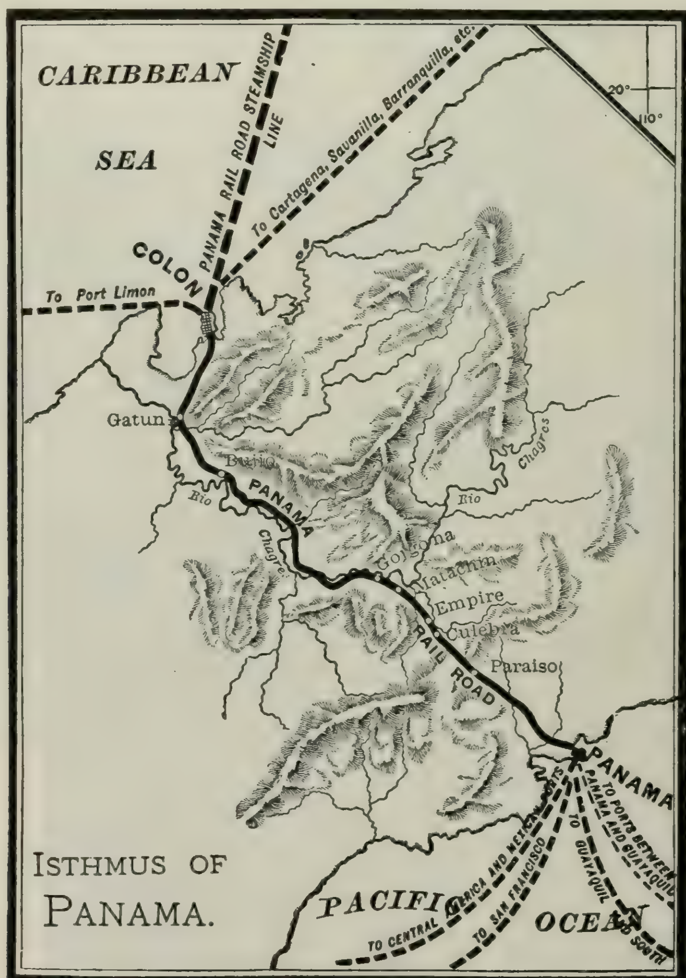
MONUMENT TO BUILDERS OF PANAMA R. R.

even now, is sufficient to excite great admiration for the men who first penetrated into this wilderness to survey the route, and for the advance force engaged in the actual work of construction.

In December 1848 the Columbian Government granted a concession to these three men for the construction and operation of a railroad across the Isthmus, connecting the city of Panama with

a port on the coast of the Carribean Sea. This port, now Colon, for many years was known as Aspinwall. In the seven years between the grant of the concession in 1848 and the year 1855 the work was completed, and in the latter year the road was opened for traffic. Today this is practically the only medium of transit across the Isthmus, the artery through which flows a large portion of the commerce of the world.

The concession granted to these promoters gave them a complete

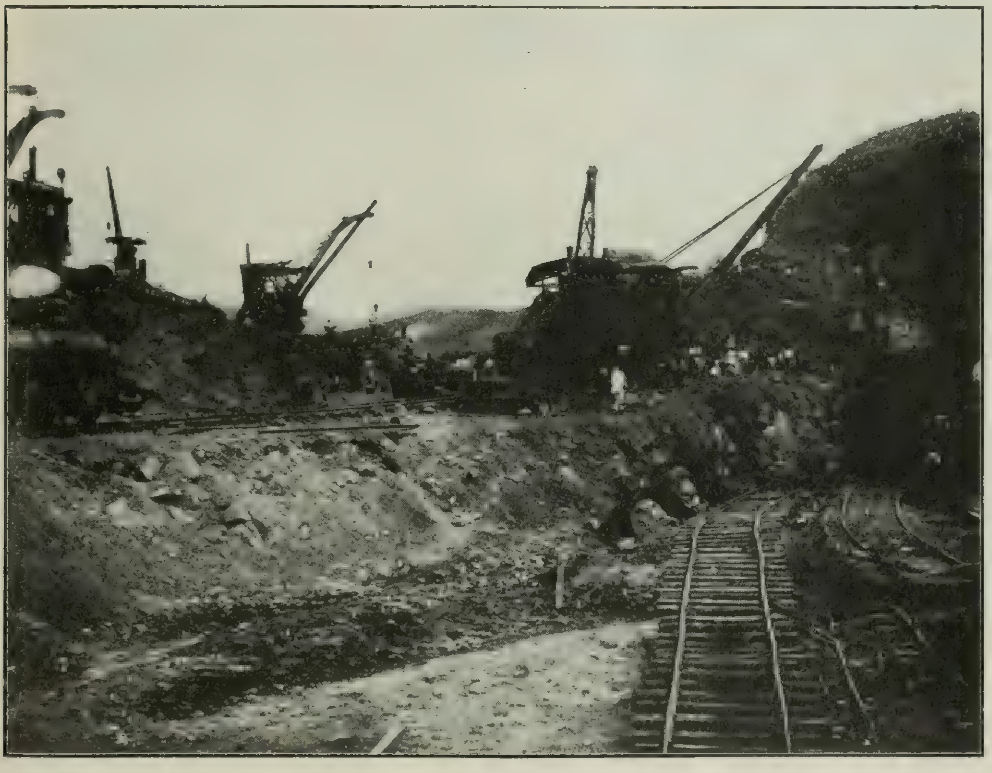



PANAMA R. R.

monopoly of the transportation facilities across the Isthmus, and the terms were rigidly enforced by the railway company, so that except by their trains there was no way of conveying produce or supplies to or from the interior points, but by pack mules or native runners. When De Lesseps went to the Isthmus to build the Canal, this monopoly of the railway company was in his way. To avoid trouble and litigation he purchased sixty-nine seventieths of the stock of the railroad company. In the purchase by the United

States from the French Company this stock was included at a valuation of $7,000,000. The outstanding stock has since been acquired and the railroad is now the property of the United States.

While in the search of a western passage in 1502 Columbus discovered Limon Bay, on the shore of which Colon is now situated. In 1513 Vasco Nunez de Balboa crossed the Isthmus with an army of about 1,200 men and from the crest of the Cordilleras beheld for the first time the Pacific Ocean; ever since that day



SOME EXCAVATING MACHINES OF FRENCH DESIGN AND CONSTRUCTION

the construction of an artificial waterway across this narrow Isthmus has been the dream of many men. There is not time tonight to tell of the many surveys that have been made since that of 1520 under the orders of Charles V. of Portugal down to October 1881 when the work of Canal Construction was begun by the French Company, organized by De Lesseps.

The preliminary work done by the French Company was considered by the Commission that recommended the purchase as about one-fifth of the whole work to be done for the construction of a lock canal. That Commission fixed the amount of money to be paid the French Company, viz., $40,000,000. In return for this sum paid them the United States acquired all their rights on the Isthmus, a canal about one-fifth completed, thousands of acres of land, hundreds of dwellings and store-houses, a revenue producing railroad and steamship line, and many thousand dollars worth

of materials and supplies that have been and can be used in our work.

Colon from its geographical position should become a city of considerable commercial importance, but the harbor needs to be greatly improved by the construction of the break-water planned by the Canal Commission for the protection of the mouth of the canal, at the same time establishing a safe harbor.

Much has been said and written of Colon of a derogatory char-

BUCYRUS STEAM SHOVEL AT WORK IN THE CULEBRA CUT

acter, and though neither Panama nor Colon are likely to be ever regarded as a health resort, yet great improvements have been made in each city within the last two years. After the grade of Colon has been raised by filling in, a sewage system can be established which will remove many objectionable features of the past.

Jutting out into Limon Bay more than five hundred feet is Christobal Colon Point. This is within the Canal Zone, is the headquarters on the Atlantic side of the Canal officials and is the Canal town. It is called Cristobal to distinguish it from Colon proper. It was the headquarters of the French Company. The surface of the Point has been raised and the shore lines are protected by rock and concrete blocks. The point is well laid out with avenues of cocoanut trees, and has lately been supplied with new drainage and water-works systems.

The principal preliminary work done by the Canal Commission was the installation of water and sewage systems in Colon and

Panama for the betterment of the sanitary and health conditions of the Isthmus and these two cities. The first work done was at Panama, as the larger and more important place. About twelve miles north of Panama, the railroad crosses one of the tributaries of the Rio Grande which flows into the Pacific. The De Lesseps Company built a dam across this stream under the railroad bridge, thus forming the Rio Grande reservoir from which water was piped about a mile to the Culebra cut. This dam has been raised to give greater storage capacity, and pipes have been laid down to convey the water to Panama. This work after many vexatious hindrances was completed in July, 1905.

There is nothing in the nature of the work to be done in the construction of the Panama Canal that is beyond the abilities of the American Engineer. They have and are constantly meeting and overcoming greater engineering difficulties than are here. The whole matter resolves itself into one of ways and means, of men and money. The Culebra cut is the greatest undertaking on the entire route of the Canal. The magnitude of the work at this point can best be appreciated when seen; the hill through which this cut is to be made is about thirty-two miles from the Atlantic and fourteen mile from the Pacific. The engineers who projected the Canal chose as the proper place to cut this obstruction, a depression in the hill, where the extreme altitude was not over three hundred and sixty-three feet. To reduce this summit down to the level called for in the plan adopted for the Canal is the undertaking now before us. "The cut" is about ten miles long. After years of work the French Company cut down the summit about one hundred and sixty feet, and removed approximately sixty million yards of material. The greater portion of the material excavated by the French Company was dumped into ravines, swamps and low places in the neighborhood of the cut, but the material yet to be excavated and disposed of is a much larger problem and will cost a good deal of money, whether done by contract or day labor. Before much progress can be made in excavating this material, necessary preparations must be made for the disposal of excavated material.

During the past two years the Canal subject has been voluminously "written up" by journalists, "special correspondents," and others. Some of these have been quite fair in their treatment of the subject but frequently formed their opinions on insufficient data. To quote a criticism of a magazine article, some months since:

"There is an ever present temptation to every capable man and especially to men of literary turn, to believe that they fully grasp the situation after the first application to its difficulties. But in about ten cases out of ten, a further acquaintance leads to a revision and sometimes to a reversion of previous conclusions. Without fear of giving offense to anyone, it may be stated categorically that the genius does not exist who can thoroughly understand the

conditions on the Isthmus by making a flying trip across it. The scene is too large to allow of rapid and exhaustive investigations, and the enterprise and its problems are on a scale too vast to admit of thorough comprehension by brief study. Maybe the observer forms a fairly accurate concept of the situation as it appears today. He thinks he has the whole thing at his fingers' ends. Tomorrow, affairs take on an entirely new and unexpected phase, revealing elements and possibilities that had been left out of consideration for the simple reason they were not known. Thus it usually hap-

CULEBRA CUT

pens that a preliminary knowledge of a subject makes a man dogmatic, while further acquaintance with it prompts to caution and reserve.

The pessimists, doubters and critics are less noticeable as every month it is more clearly seen that "there are no problems connected with the Panama enterprise which are insoluble or which cannot be readily solved by good engineers and administrators. There is no call for miracles, but simply for a great lot of ordinary labor, intelligently directed and applied. The difference between the enterprise at Panama and any of a dozen others that might be named, is one of degree, not of kind. It is a job just like others that have been successfully performed, excepting that it is bigger than any of them. That is all."*

*A statement made by the First Chief Engineer.

# THE DEVELOPMENT OF MECHANICAL FILTRATION.

Robert E. Milligan, M. W. S. E.

*Presented May 2, 1906.*

In February, 1902, I had the pleasure of reading to you a paper which endeavored to explain Mechanical Filtration and the field it covered and the results obtained by it, in reducing water borne disease and guarding against epidemics. The four years just elapsed have shown a remarkable increase in the use of this method of purifying water and many of those who once opposed its use, preferring to advocate its sister process, slow sand filtration without coagulants, have become advocates of Mechanical Filtration, while continuous usage and accumulated data substantiate the fact that when properly used in conjunction with well designed mechanical filtration plants, the aluminum or iron salts used as coagulants are harmless, and their use in this connection above criticism.

It is worth stating that little or no change has occurred in the mechanical filter *per se* in the preceding four years so far as the principles governing the machine itself are concerned. Concrete construction is, however, gradually asserting itself over the earlier wooden or steel tanks and this change is logically the beginning of the development of mechanical filtration to its ultimate acceptance by the larger cities as the most economical as well as the most efficient method of purifying polluted water supplies. The use of concrete in the construction of filters, permits of the rectangular unit, which for a given area occupies less ground than the circular tank, and to those who have never seen mechanical filtration in operation the following illustrations will indicate my meaning.

Fig. 1 is from a photograph of the Jewell Type at East Albany, N. Y., on the Hudson river, and is constructed of cypress, each unit being a tank 15 ft. in diameter, of which there are six, constituting a plant of 3,000,000 gallons capacity in 24 hours.

The plant at Ithaca, N. Y., consists of 6 one-half million concrete units aggregating 3,000,000 gallons per day. This was installed during the typhoid epidemic the latter part of 1902 and early in 1903. Each of these concrete units is 11 ft. by 16 ft. in plan as against the circular diameter of 15 ft., and the total ground space occupied by the Ithaca plant is 50 ft. by 38 ft., while the East Albany plant takes up approximately 51 ft. by 55 ft. This is a fair comparison of the filter space in each plant and does not include settling basins and clear wells.

The Ithaca plant is operated by valves having extension stems and hand wheels similar to those employed in connection with the one-half million gallons cypress units shown in Fig. 1. Later you

may note the development of labor saving devices in connection with concrete construction, made necessary because of the magnitude of the plant at Little Falls, N. J. The wooden construction is limited to the length of stave obtainable for a circular tank and today it is difficult to obtain 22 ft. of clear cypress lumber; this diameter, equal to 380 sq. ft. of area, constructs a tank of 1,000,000 gallons capacity in 24 hours, on a basis of 125,000,000 gallons per acre, which is still the recognized rate of flow in mechanical filtration. Concrete and steel units can, of course, be constructed of any capacity, only limited by the washing devices. In this connection the use of agitators to assist in washing are practically confined to circular tanks, while the "air wash" has been adapted to the rectangular tanks of concrete construction, and is, indeed, a distinctive feature today of the rectangular unit. My experience indicates that the agitator has some advantages over the "air wash" in economy, especially where turbid supplies are filtered. A circular concrete Jewell filter agitator is shown in Fig. 2.

FIG. I—INTERIOR FILTER PLANT, EAST ALBANY, N. Y.

Abroad, the Jewell Export Co. have installed large filtration plants, sometimes of steel and often of concrete construction, but always circular, in order to permit of the use of the agitating device. Very satisfactory results have been had even, with the turbid waters of the Nile, at Alexandria, Egypt.

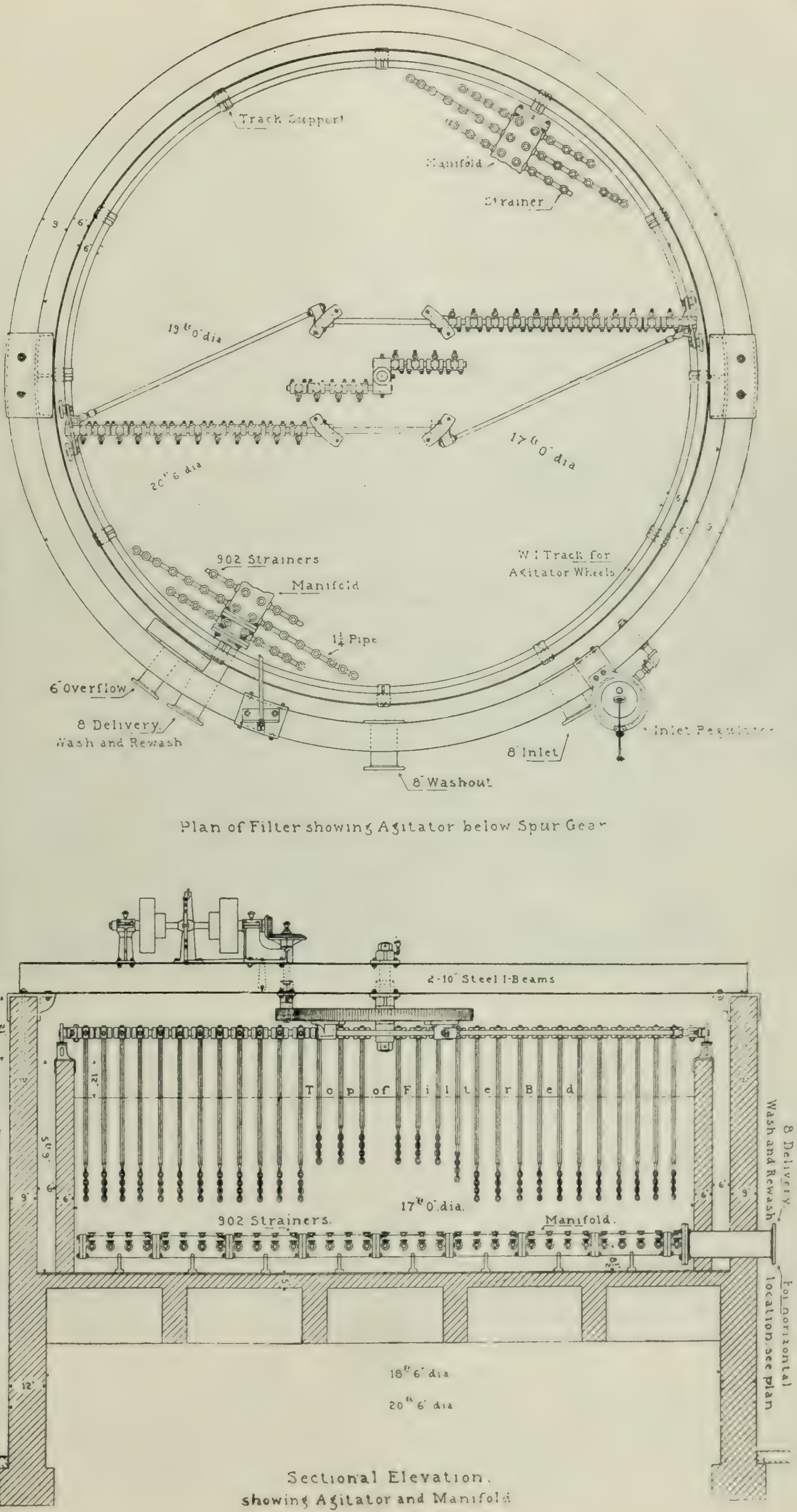



FIG. 2

17 foot Reinforced Concrete Jewell Gravity Filter.
(Steel reinforcements not shown.)

Such filter efficiencies as are had at Ithaca, N. Y., Little Falls, N. J., and Moline, Ill., etc., averaging 98 per cent. bacterial reduction, all based on rectangular concrete units with air wash systems, leaves the issue an open one, though in economy of wash water the evidence is somewhat in favor of agitators.

There are locations peculiarly favorable to pressure filters, and from a mechanical and engineering point of view their installation is indicated, and in such cases as have come recently under my observation, notably Norwich, N. Y., their performance has been

FIG. 3—GENERAL VIEW, FILTER PLANT, ETC., LITTLE FALLS, N. J.

eminently satisfactory. The development of mechanical filtration is nevertheless along the line of the gravity or open filter, and no better evidence of this exists than the 32,000,000 gallons plant of the East Jersey Water Co. at Little Falls, N. J., purifying the waters of the Passaic River. The illustration Fig. 3 shows the power pumping plant and its situation on the river bank, while Fig. 4 shows the general view of the filter plant on the river bank below the power station. The plant is constructed of concrete wherever concrete is possible, even the building walls being composed of concrete blocks, made in forms, of almost dry concrete and stained to appear like sandstone having a semi-rough finish. The illustration Fig. 5 shows the wing view or rear of the building, each wing having a filter gallery, the filters extending from the gallery beyond the building, as shown in the foreground. An interior view of the east gallery is shown in Fig. 6. There are two

of these galleries, which have concrete platforms (covering the pipe galleries), on which are set the operating tables, one for each

FIG. 4—LITTLE FALLS, N. J.

filter. On either side of this platform the filters open, 8 on a side, or 16 filter units in each gallery, making 32 filter units in all; each unit is 15 ft. by 24 ft. and 8 ft. deep. A very complete article

FIG. 5—REAR VIEW, LITTLE FALLS, N. J.

on this plant was published in the American Society of Civil Engineers, Feb., 1903, soon after its completion, by Geo. W. Fuller, C. E., from which I quote: "The coagulating basin (situated under

the main building) and the clear water well (under the filter units) are of concrete. Reinforced concrete after the Ransome system was used for the construction of the filter tanks, all floors and the walls of the houses and the roof of the filter tanks. No wood was used about the building, except the doors and windows. Each filter tank was built as a continuous box of concrete reinforced with twisted steel rods in each direction." The concrete used in these tanks was mixed in the proportions of about 1, 2 and 4 and was laid very wet. "Vulcanite" cement was used principally for this portion of the work. All the filter tanks were plastered on the inside with a 1/4 in. coat of rich mortar in the proportion of one part cement

FIG. 6—INTERIOR, EAST WING, LITTLE FALLS, N. J.

and one part sand, etc. In no instance have there been any cracks or leaks in these filter tanks. This last assertion can be reiterated now, four years after the construction of the plant.

The "Continental air-wash" is used in connection with these filters, there being two (2) No. 3 Root Blowers direct connected with electric motors; each Blower has a capacity of 1,500 cu. ft. of air per minute under a pressure of 5 lbs. One of these Blowers is utilized to furnish about 1,000 cu. ft. per minute of air, under 3 lbs. pressure to the filter being washed. The strainer system distributing this air under and through the filter bed by the usual header or manifold arrangement contains 1,316 Continental tapped strainers in each filter. These strainers are of hard cast and cupped

brass; the neck or extension of the strainer is a 3/8 in. brass tube extending into the cast iron lateral distributing pipe about 1¼ in., and this extension constitutes a trap within the lateral pipes and forces the air to escape through the perforation in the upper part of the extension tube. This perforation is 3-32 of an inch in diameter, and the total of these perforations offer an area found most practical in distributing the necessary volume of air to wash the filter. The result is its even distribution throughout the filter bed. This method of distributing the air in washing filters is in successful use at Cairo, Danville, and Moline, Ill. The wash water is supplied from the clear water basin by centrifugal pumps electrically operated, one pump and motor in each pipe gallery. They operate under less than 25 ft. head, and discharge 3,000 gallons per minute. The total operation of washing requires eight minutes, that being the time used to wash each million gallon unit. The average wash water used in 1903 and 1904 was 2.8% of the water filtered. Three men, each working eight hours per 24 hours, under a Superintendent, operate this filtration plant which is at times run at the rate of 50,000,000 gallons per day; practically the same results are had at that rate as at the guaranteed rate of 32,000,000 gallons per day. The average sulphate of alumina used in 1903 and 1904 was 1.26 of a grain to the gallon of water filtered and the average bacterial efficiency was equal to 98% reduction. An average of 17,200,000 gallons of raw water was purified per day during 1903 and 1904.

The next illustration (Fig. 7) shows the operating table on which are the controls for the operation of the filter; all the valves are double-disc gate valves operated by hydraulic cylinders. These cylinders are operated through a separate high service line controlled by special four-way cocks. The levers operating these are provided with indicators showing the position of the valves and are located on the operating table. Beyond setting these levers there is no labor in operating the filters. Each filter is controlled on its effluent line by a "Weston Automatic Controller," which prevents a higher rate of discharge from the filter than its rated capacity. To this controller is added a well and float, operating an automatic "loss of head" gauge, which indicates the resistance offered by the filter bed, and the accumulation of matter on the filter which had been removed from the water passing through it, as it expresses the loss of head in feet and fractions thereof between the water entering the filter and that leaving through the controller. As this device is novel and was designed to fill this requirement and to replace the "Dibblee gauge" heretofore in use, I will describe its principle. The dial is movable and is operated by a float located in the water above the sand bed of the filter. Any variation in the water level on the filter is at once shown by the position of the dial in its relation to the fixed point on the rim or periphery of the metal case. The pointer operated from the center of the dial, like the hands

of a clock, is independently operated by a float located in the stand pipe or well fed by the effluent controller, so that the relative positions of the dial and the pointer are in relation to the relative elevations of the water level on the filter and the water level in the

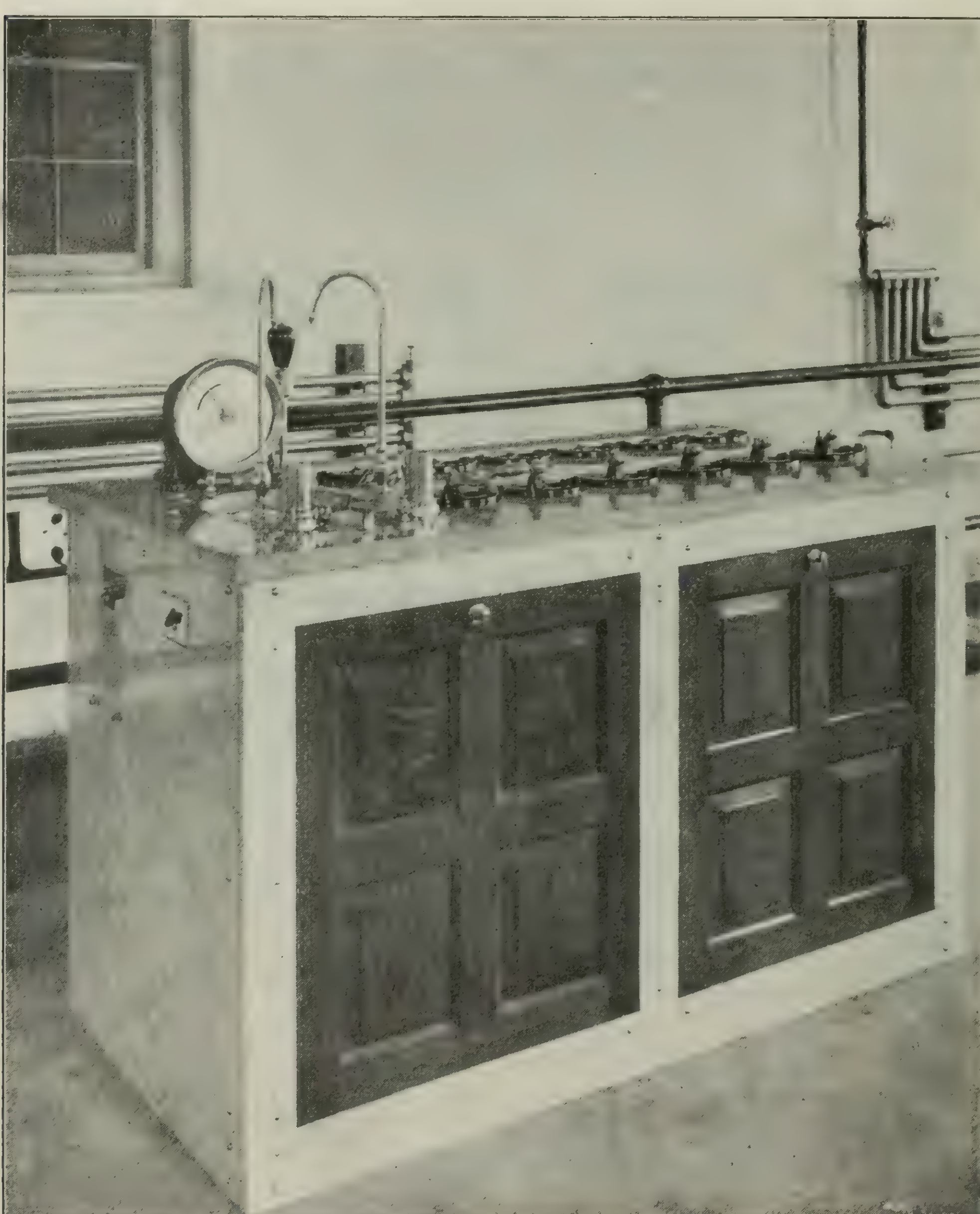


FIG. 7—OPERATING TABLE, LITTLE FALLS, N. J., PLANT

stand pipe or well, fed through the effluent controller, and the difference in the positions of the dial and pointer gives the loss of head. In the beginning the normal loss of head is ascertained and the instrument corrected to discount it, so that a direct reading is obtained by the operator, and the error caused by variation of the head on the filter is avoided. Electrical connection from the float

operating the indicator causes a bell to ring and a light to show that the maximum loss of head has been attained, thus warning the operator when it is time to wash the filter.

Although several large plants have been erected since the installation of the "Little Falls" plant, they differ only in minor detail and it is generally conceded that this plant represents fairly the greatest development in mechanical filtration to date. For some time the filtration engineer and chemist have been investigating coagulation in water in conjunction with settling basins and filtration plants, and as it is upon the proper coagulation of the water prior to filtration that the mechanical filter largely depends for its efficiency, this research will, it is hoped, result in greater uniformity of result obtained.

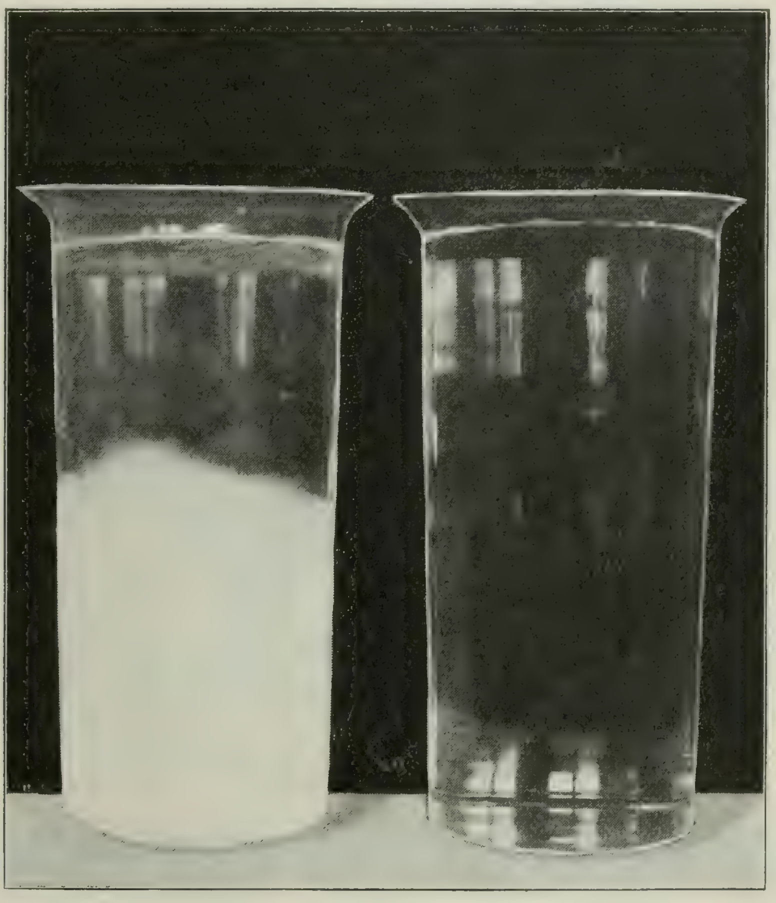


FIG. 8—EFFECT OF TIME ON ACTION OF COAGULANT

Many waters are deficient in the alkalinity or native carbonates, that are relied upon to decompose the coagulant used, and it becomes necessary to add lime and soda to effect the decomposition of the alumina or iron salt used. This added "alkali" does not in every instance quickly produce the flocculant coagulum needed in conjunction with the filter plant. The reasons for this are obscure and

not determined absolutely. The time element in some cases solves the difficulty, though there are cases to the contrary apparently. The tendency, however, is to install coagulating basins with the modern filter plant even where there is little or no suspended

FIG. 9—ROUGHING FILTER, YORK, ENG.

matter in the raw water. The development of the coagulum in a beaker of water, after standing one hour, is shown and the value of time in this connection will be appreciated. Outside of this factor,

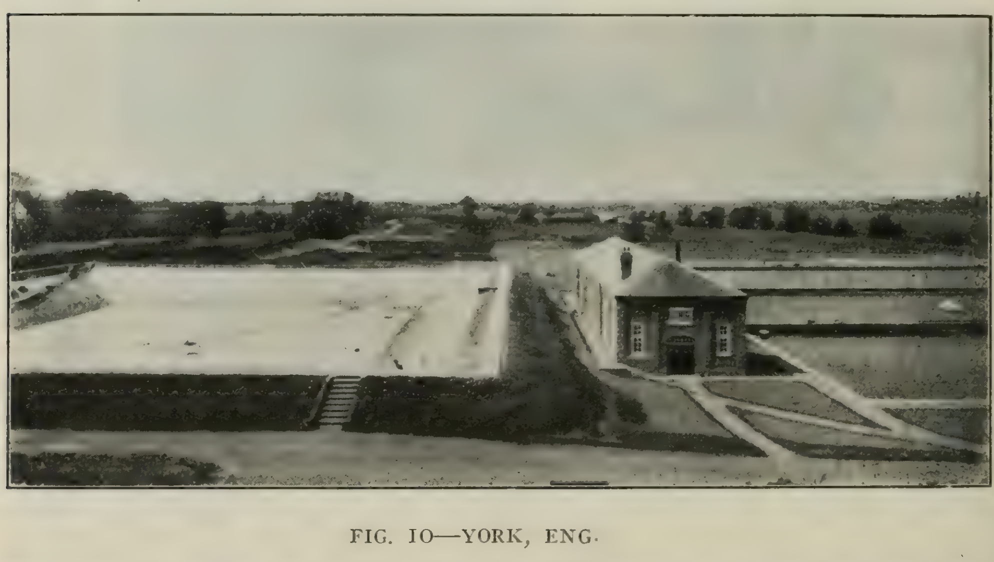


FIG. 10—YORK, ENG.

attention is called to the marketable sulphate of alumina used as a coagulant. This is quite variable in its chemical composition and it is probable that some of the difficulty that occurs in coagulating

water is due to the presence of an excess of acid over the base. In "The Journal of Infectious Diseases," February, 1906, Whipple and Longley have gone exhaustively into this phase of the matter and "suggest that specifications for filter alum shall always require that there shall be a substantial excess of alumina, that is, that the alum shall be distinctly basic. This is usually so in any case when the available alumina exceeds 17.5%." This suggestion seems a good one to the writer.

The use of roughing or preliminary filters in connection with slow sand beds has received some consideration in the last four

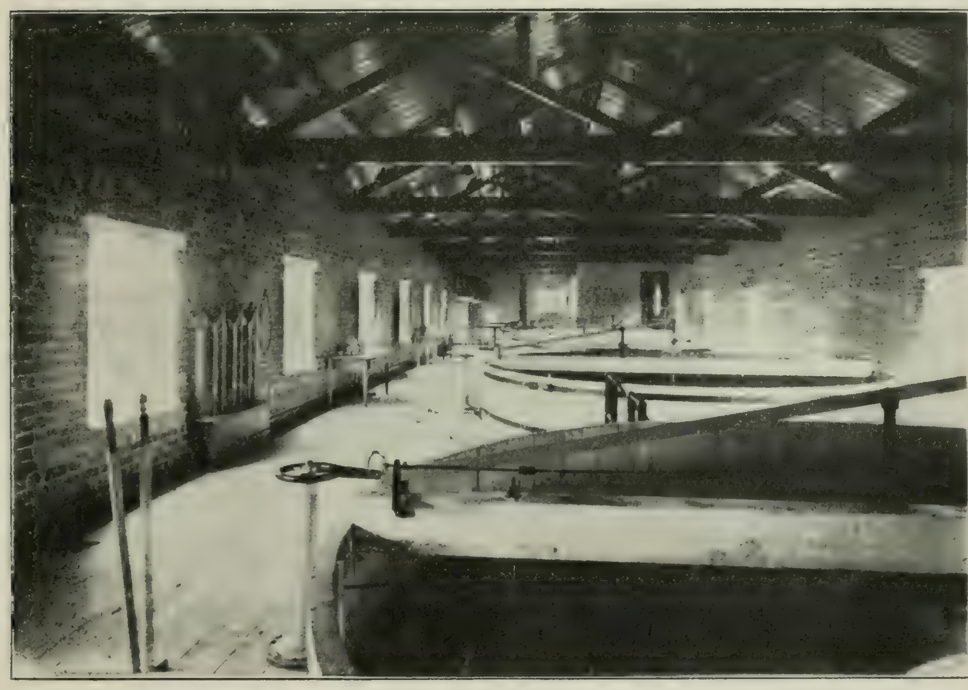


FIG. II—INTERIOR FILTER PLANT, YORK, ENG.

years. The city of Philadelphia contemplates the addition of this type of filter to render the slow sand plant, already constructed, operative and efficient, and Pittsburg embodies their use in the plans for a slow sand plant now being installed. These preliminary filters are substantially mechanical filters operated at a lower rate than the prescribed 125,000,000 gallons per acre at which mechanical filtration is operated to secure high bacterial efficiency, and their use at all in this connection seems to be in order to avoid the use of coagulants in connection with slow sand beds, operating at about 3,000,000 gallons per acre. Outside of prejudices, I believe the installation of mechanical filtration on those plants where slow sand filters had been installed and roughing filters afterwards found necessary to render them operative, would have been better practice, alike for economy and efficiency.

There is nothing novel in the practice of preparing the influent to slow sand filters through roughing filters and Fig. 9 shows the roughing or preliminary filter house at York, England. These mechanical filters were installed about six years ago as an adjunct to the slow sand filters previously constructed; Fig. 10 gives a general view showing the settling basin, mechanical filter-house and slow sand beds, while Fig. 11 gives the interior view of the mechanical filter house at York, England.

From the standpoint of the advocate of mechanical filtration the bill to permit the use of coagulants in connection with the slow sand filtration plant just completed at Washington, D. C., is significant. This bill is known as H. R. 9748, 59th Congress, and was introduced by Mr. Wiley of New Jersey. If it passes, it will no doubt have its effect upon those who doubt the expediency of using coagulants in the purification of polluted or turbid water supplies.

DISCUSSION.

*Daniel W. Mead,* (M. W. S. E.)—I have been interested in what the author of this paper has to say in regard to the development of Mechanical Filtration. The author, as is well known, is connected with the "New York-Continental-Jewell Filtration Company," and in this paper he has mentioned particularly the devices which are owned and controlled by that Company. It is well to note that, while much of the new construction of mechanical filtration is being done by the filter companies, yet at the present time two of the largest plants that are being constructed, namely at Louisville, Ky., and at Cincinnati, O., are on plans by engineers who are not associated with any of the filter companies. It can be truly said at the present time that a high grade mechanical filtration plant can be successfully designed and installed without the use of any of the various patent appliances that are owned by the filter companies. In many cases, however, these proprietory appliances are of considerable value, and well worth the careful consideration of the engineer. These companies, however, do not control mechanical filtration, and any engineer who is thoroughly acquainted with the subject can successfully design, install, and operate filters of this class.

Few of the filtration systems in operation at the present time can be regarded as entirely successful. They are successful as compared with others that have been used previous to their installation, but I believe they still leave much to be desired.

The filtration systems mentioned by the author under what he terms "roughing in filters" is a move in the right direction, an attempt to improve the quality of our filtered waters.

One of the greatest difficulties in connection with filtration plants is in the management of the filters. It is comparatively easy to design a fairly perfect engineering work and fairly easy to obtain first class construction. It is, however a very much more difficult

matter to secure services that will accomplish successful operation every day in the year and every moment of the day, and without such operation the filter only partially fulfills the work for which it is designed.

I do not wish to be understood as stating that filters are not doing good work, or that I do not believe that the are well worth the trouble and expense of their installation. They have very greatly improved the quality of our water supplies and have undoubtedly saved many lives where polluted supplies were previously in use, but I believe the water turned out by the filter systems of this country is not, as a rule, as good as we should expect to obtain, and this is largely due, not to the fault of the filters, but to our method of managing public works in this country. While not personally acquainted with the civic conditions in Europe, I am led to believe that much better results are obtained there, largely on acount of the fact that their method of control is different and better than ours. In this country we pay too much attention to the politics of the man who is to operate the filter system, instead of his ability, and on this account very poor results are often obtained. In order to obtain proper results, a man must be thoroughly well skilled in the handling of filters and without such skill and without considerable experience with the particular water of the locality and with the particular methods used in the plant, I believe success cannot be obtained.

In the Danville filters, a description of which was read by the speaker before this Society about a year ago, we had considerable difficulty in getting the filters into successful operation, although we had with us at the time, men who had had considerable experience in that class of work. One of these was a chemist who had devoted the greater part of his time for many years to this matter of water purification. He was, however, an eastern man, unused to western waters. Although skilled in the general subject, he was unable to bring the filters to the degree of efficiency that we had a right to expect. This difficulty was remedied later by a sanitary chemist, who had had experience with such waters. I mention this fact to show the necessity of the operator being familiar with the particular plant and the particular water that he is to handle.

Referring to some of the illustrations presented by the author, I wish to call your attention to two points in regard to the same. In the Little Falls plant the filter operating buildings, Figs. 5 and 6 is comparatively narrow, and simply covers the ends of the filters. The larger portion of each filter is covered with a low roof, and is not accessible except when the filter is empty. In this case, only the front ends of the filters are where they can be seen. In the same plant the coagulating basins also are covered, keeping the operations that are going on in them out of sight, more or less. In filters, as in other works, out of sight is out of mind. The speaker believes that filters should be exposed to view for their entire length.

It is very desirable to have the coagulating basins in the building, and in a location where they can be readily seen and examined by those in charge. Better results can be obtained if the entire filter is exposed and can be examined during the progress of filtration.

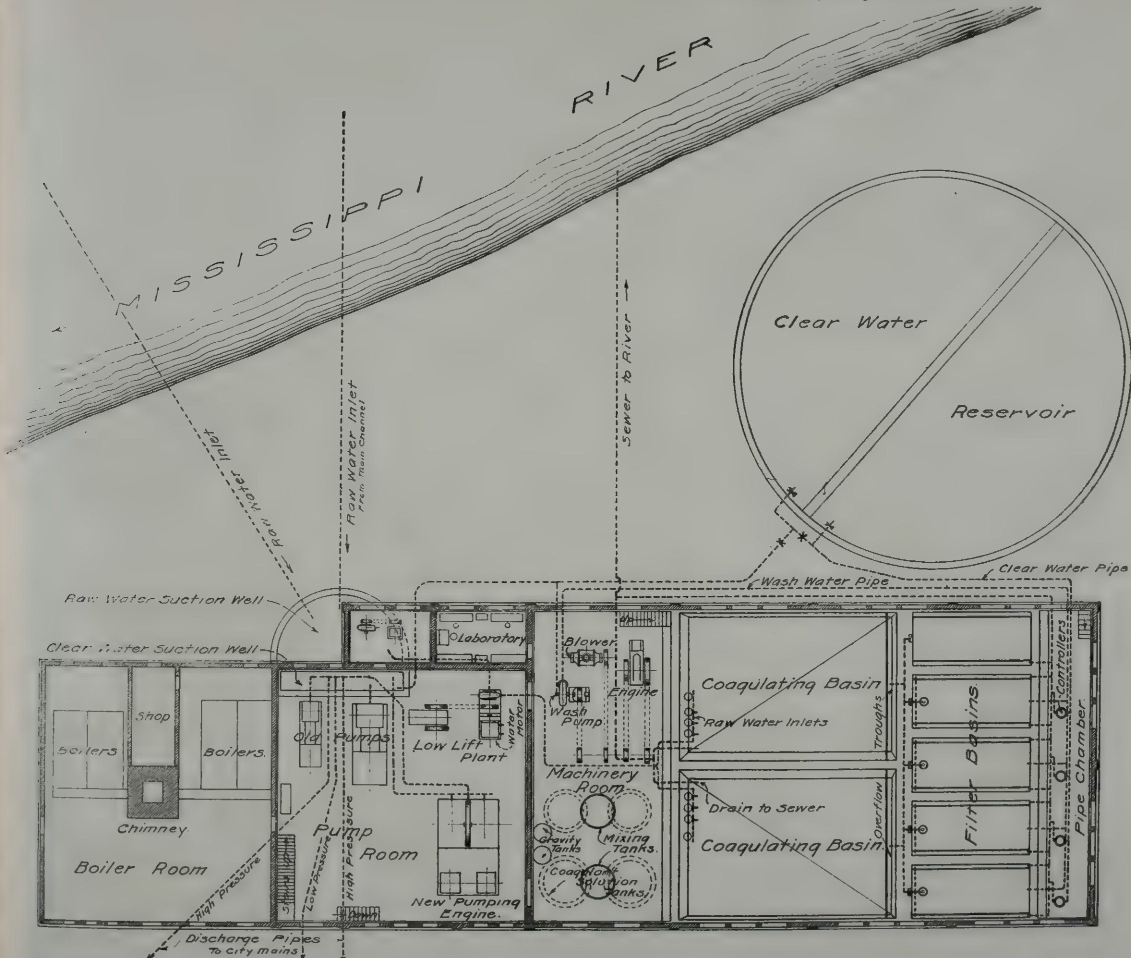
Referring to the Continental air wash, of which the author speaks, and which is in use both in Moline and Danville, where the Continental screen is used, the idea of this screen is that it may be used as a strainer to pass the water from the filter to the underdrain and on to the clear water basins. It is also used as an inlet for the air and water for washing. The water is admitted by reversing the current and forcing the water back. The air wash consists usually of a wash first with water and then with air. The air in the Continental wash is forced back through the same pipe system, passing along the upper portion of the pipe, and finds admission to the strainers through the holes near the top of the filter screen stem. This screen is patented. In a great many cases where the air wash has been used it has consisted of an independent system of air pipes laid alternating with the strainers, so that the water wash will pass up through the strainer, and the air is admitted through the independent pipe system. The results are essentially the same in both cases. There is more than one system of air washing which has been and can be successfully used. It is also a question whether it is not possible to wash the filters by water entirely without air, and without mechanical stirring devices. I understand that such a process will soon be attempted in the Cincinnati plant.

The author mentions, among others, the plant recently designed by the speaker, and which was constructed and equipped with apparatus by the New York Continental Jewell Filtration Company, namely, the plant at Moline, Illinois. I wish to call your attention to a few illustrations of this plant, and to discuss in connection with it some of the points that I consider quite essential for the proper design and operation of filters.

In Fig. A is represented a general plan of the water works at Moline. The boiler and pump room shown are the original plant, to which was added the filter building shown on the left, and the clear water reservoir which adjoins it.

On this plan is shown the inlet pipes from the Mississippi River into the suction well. From this well the water is raised by a low lift pumping plant, and pumped into the coagulating basins, through which it flows into and through the filters.

The arrangement of the filter room is shown in greater detail in Fig. B. At the left of this, is shown the original pumping station, in which the low lift centrifugal pump is placed. The coagulating solution tanks are placed below the floor of the machinery room. The mixed coagulants are pumped into gravity tanks, from which they flow into the raw water just before it enters the coagulating basins. The water passes into the coagulating basins through

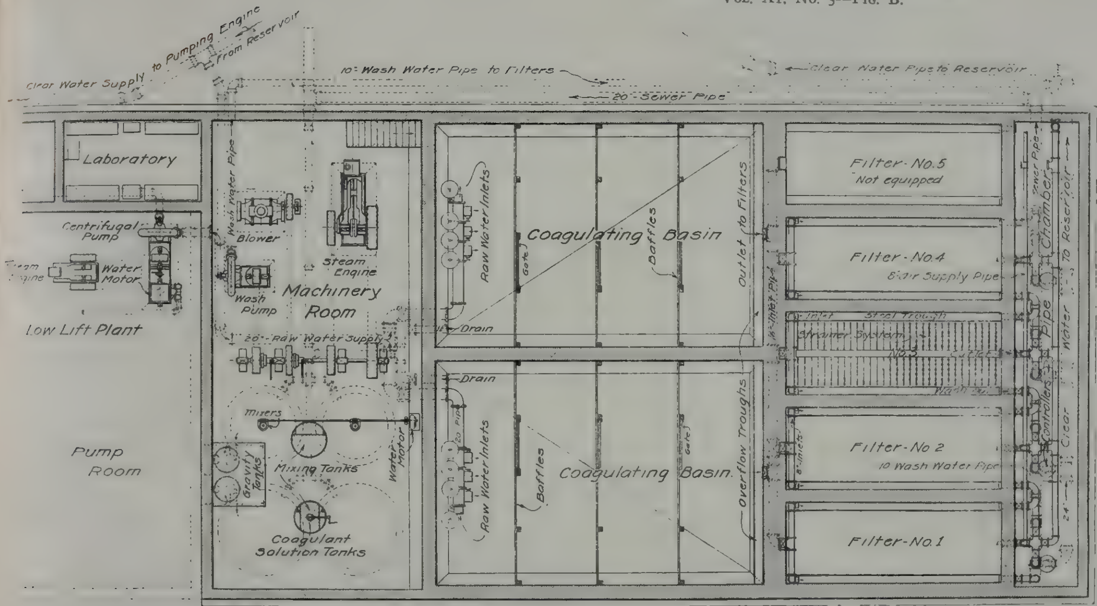



GENERAL PLAN OF WATER WORKS.

It is
and in
those
expose
Ref
speaks
the Co
be use
drain
for th
versin
consis
air in
systen
missio
screen
the ai
tem o
water
ted th
ly the
washi
questi
tirely
unders
cinnat

The
by th
appar
namel
to a fe
it som
design
In
Moline
to wh
clear
On
into th
lift pu
which
The
in Fig
tion, i
lating
room.
which
lating

Journal Western Society of Engineers.
Vol. XI, No. 5—Fig. B.




PLAN OF FILTER PLANT.

Scale 0 2 4 6 8 Feet

It
and
thos
exp

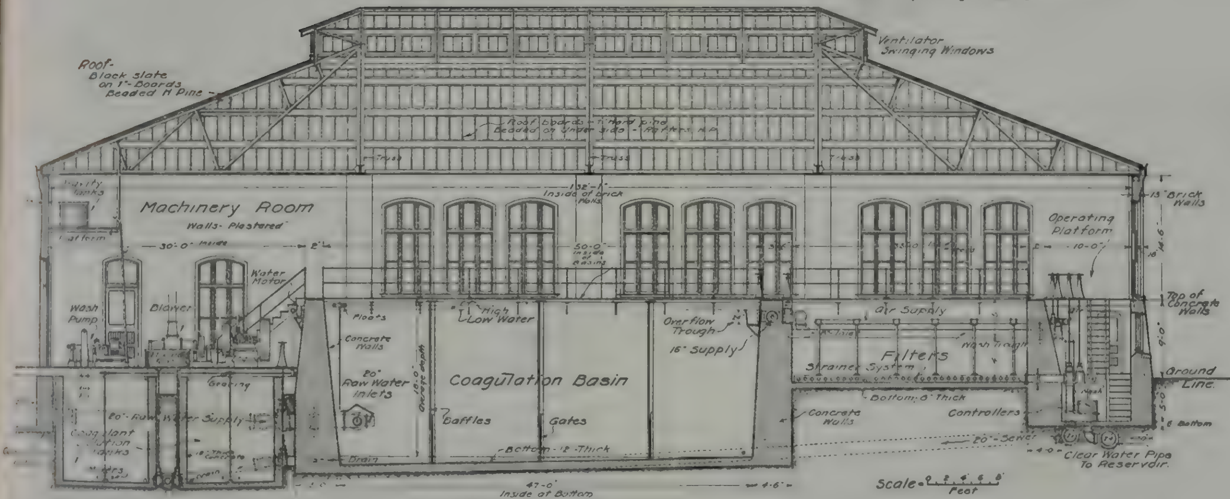
R
spea
the
be t
drai
for
vers
con:
air
syst
mis
scre
the
tem
wat
ted
ly t
was
que
tire
unc
cin

T
by
app
nar
to a
it s
des

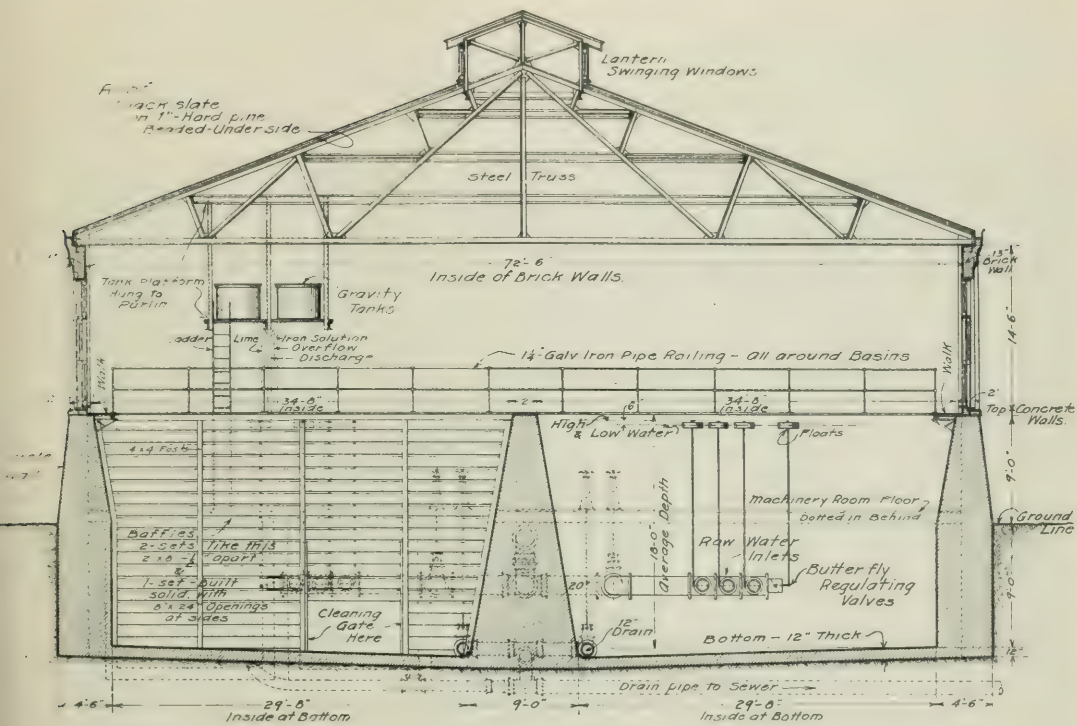
I
Mc
to
clea

(
inte
lift
wh

in
tion
lati
roo
wh
lati



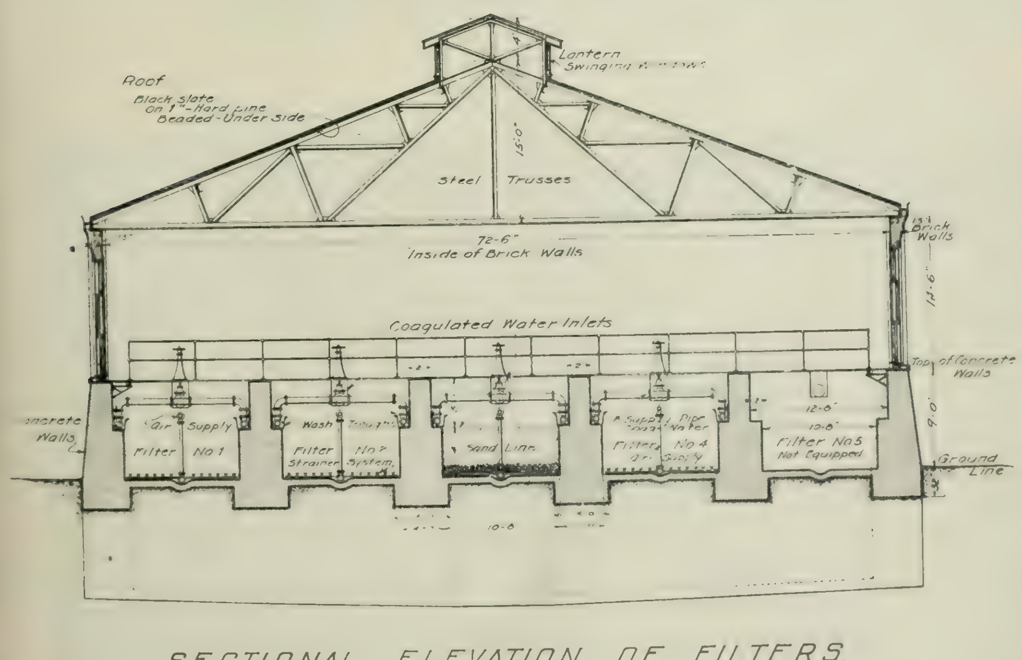

LONGITUDINAL SECTIONAL ELEVATION.




SECTIONAL ELEVATION OF COAGULATION BASIN.

Scale = 0 2 4 6 8 Feet

FIG. D

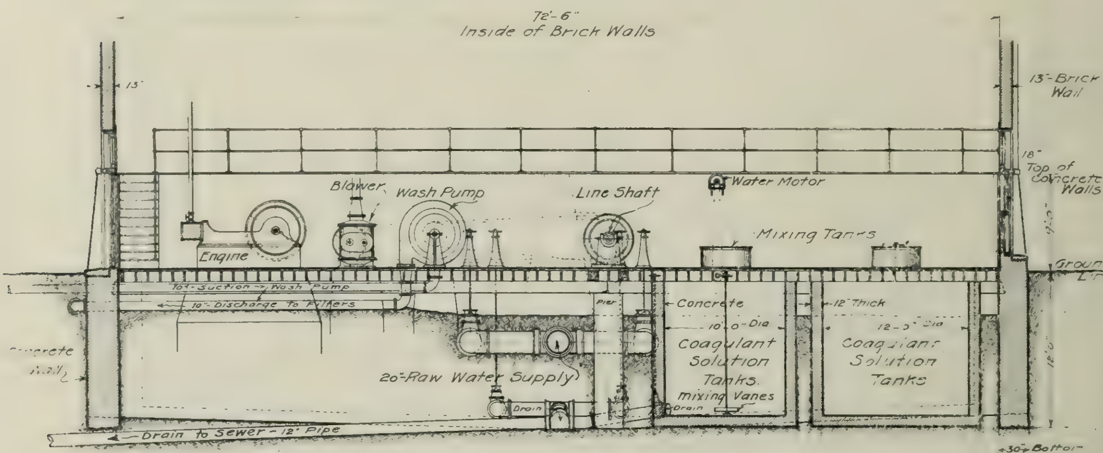



SECTIONAL ELEVATION OF FILTERS.

Scale = 0 2 4 6 8 Feet

FIG. E

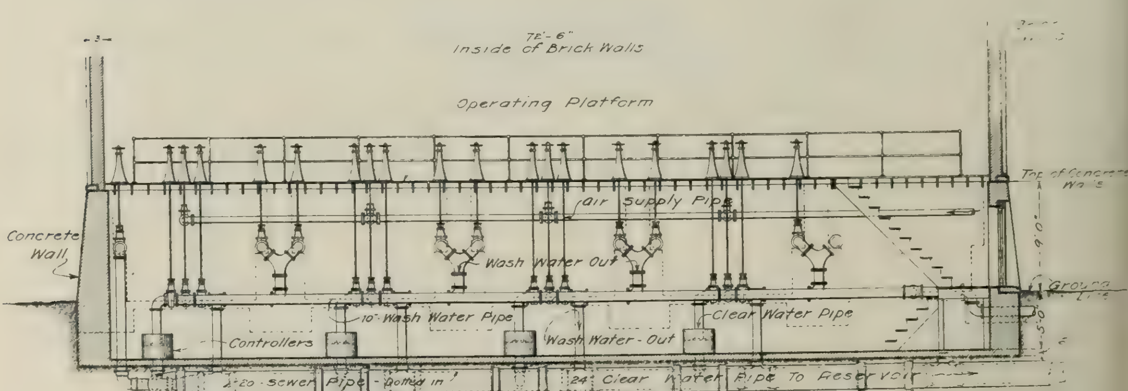
four (4) inlet valves, controlled by floats. The water passes slowly through the coagulating basins, being distributed uniformly by means of baffles. At the farther end it overflows in a thin film into a trough, from which it is distributed to the five filters. The water passes downward through the filter sand and out through the screen system and outlet pipes to the clear water reservoir.




SECTIONAL ELEVATION OF MACHINERY ROOM.

FIG. F

A vertical section through the plant is shown in Fig. C, which is, I believe, in sufficient detail to make an extended description of the same unnecessary. Further details of this plant are shown in Figs. D, E, F and G.




SECTIONAL ELEVATION OF PIPE CHAMBER.

FIG G

In Fig. H is a view of the plant from the platform on which the gravity coagulent tanks rest. In the foreground are the two coagulating basins, while the five filters are shown at the other end of the room. The building is 135 ft. in length by 72 ft. in breadth, and is well lighted both by day and by night, in order that the operation may be carefully watched.

In Fig. I is a view of the machinery used for operating the filters. At the left is an ordinary slide valve engine, which is used to operate the blower and wash pump. The blower shown in the center of the

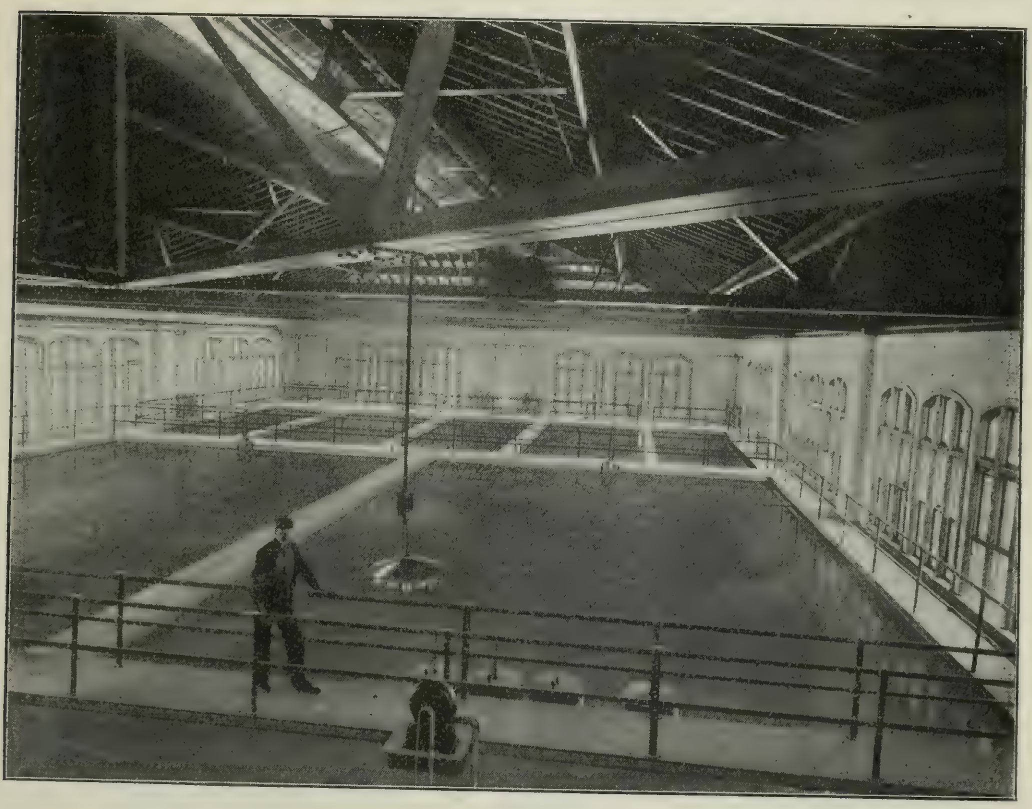


FIG. H.

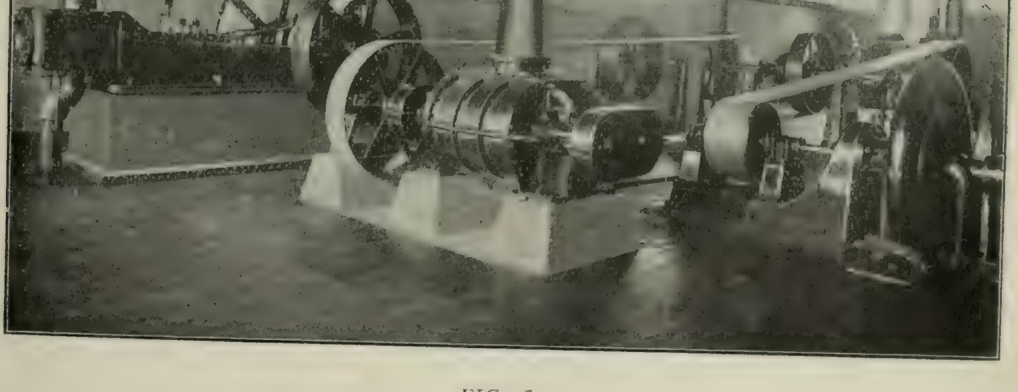


FIG. I.

picture furnishes the air necessary for the air wash, and the water for washing is furnished by the centrifugal pump, on the right, which takes its water from the clear water basins and forces it back through the pipe screens and filters.

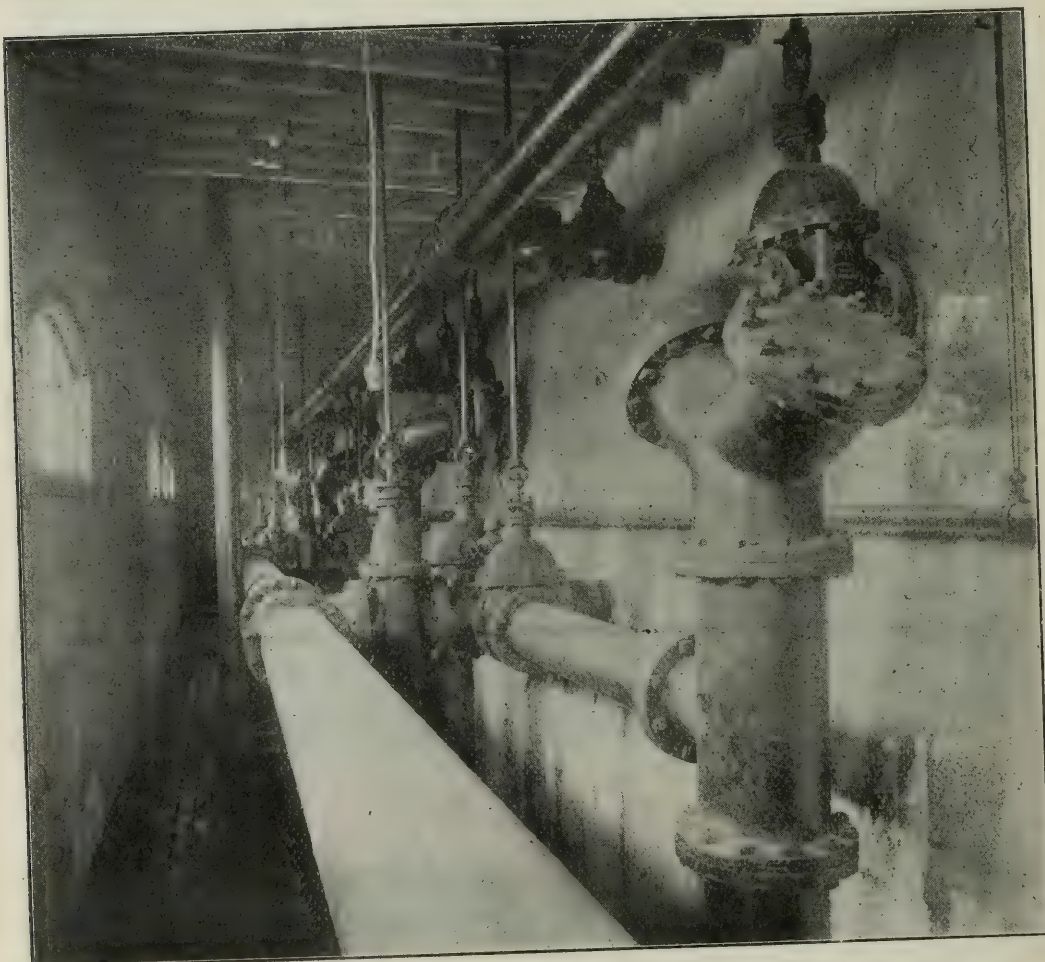


FIG. J.

In Fig. J is a view of the pipe in the pipe chamber which is shown in some detail in Fig. B.

In constructing this plant one of the main ideas was to so build it, that those in charge should have as full knowledge as possible of what was going on in the coagulating basins and filters. For this reason, the plant is constructed in one large building, that those in charge must pass by the coagulating basins in going to the filters.

The filters are designed for a capacity of 1,000,000 gallons each, at the rate of 125,000,000 gallons per acre per day, which is the rate ordinarily adopted for mechanical filters.

From the author's paper, it will be noted that such filters, under suitable conditions, can be operated at much higher rates, the rate depending both on the character of the water, as well as various other conditions. The rate named is used, principally because it

has been used for a great many years, and is the basis of design of most of the successful mechanical filtration plants now in operation. For this reason, in the Moline filters this precedent was followed, rather than to attempt to establish a new one, under conditions which could not be fully determined until the filters were in use, without long-continued and expensive experimental work.

Professor E. G. Smith, (M. W. S. E.), of Beloit, made the final test of these filters. During this test, one point of particular interest came to the speaker's attention. Daily reports were sent to the speaker as to the results obtained. It was noted that at one time the filters were doing poor work, when there was apparently no particular reason for such condition. At that time the city was using only about 2½ million gallons of water per day. Both of the coagulating basins were in use, going through an eight-hour period of sedimentation, instead of the 4-hour period, for which the basins were designed. After knowing these conditions, the speaker caused one of the basins to be closed off, and the time of sedimentation reduced to 4 hours, after which much better results were obtained.

The time of sedimentation after coagulation must be limited. It must not be too short, neither must it be too long. With sulphate or iron, which was there used, the coagulating material settles rapidly, and all of it was left in the coagulating basins, none being carried over on to the filter. In order to secure satisfactory work from a mechanical filter it is necessary that a certain amount of the coagulant should be carried into the filter to form the gelatinous film, which takes the place of the natural formation or *"Schmutzdecke"* of the slow sand filters.

The result of the test made on the filters showed that a high rate of efficiency could be obtained by proper operation. The speaker is not familiar with the results that have been obtained in that plant since it was placed in service. The filter has, I believe, been operated entirely by men unfamiliar with bacteriology, and who have had no previous experience in filtration work. He is of the usual type of operator in charge of the filters of the country. The main idea of such men in operating filters is to turn out a water that is good to look upon; that is to say, a water which is clear and colorless. Fortunately, very fair results are secured in this way, but no such results as the water users have a right to expect. Filters so operated, in each case have efficiencies of about 80 to 85%, instead of the higher efficiencies of 98 or 99%, which can be obtained by skilled management. In order to secure these better results, it is necessary to have skilled men in charge, who are familiar at least with certain elementary bacteriological and chemical information, and who will become practically familiar with the particular water, and with the way it should be managed in every case. Until such men are placed in charge the best results of filtration cannot be gained, and filtration cannot be called entirely successful.

*Mr. John P. Denison*—There is one phase mentioned by Mr.

Mead which is about the only thing not fully touched on by him. That is, the question of washing the filters without any agitation of sand at all. That has always been a problem to people in the filter business on waters which contained practically no matter in suspension. Of course a filter plant constructed rightly, contemplates the filter doing only the lighter work, the larger portion being done in the settling basins where perhaps 90% of the suspended matter is removed. It has been thought then that nearly all classes of water could be put in the same class so far as washing is concerned. If you have a water containing little suspended matter and water containing a great deal, it was thought if a large percentage was removed in the settling basins the two waters coming to the filters would be really classed alike, the filters doing only the lighter work. At Little Falls a great variety of experiments were made, from the time that plant was started in operation. Some of the filters have been run at different rates from others, and have been operated with a great deal of variation. Some of the filters were operated without using any air whatever in the washing. For some time they got practically the same bacterial removal. The wash water required was a little over 1% more as compared with the filters being washed with air, and it was looked on as a matter of dollars and cents as to whether the extra amount of wash water cost more than the power to run the air blower. These filters ran along for so long a time with no falling off in the efficiency, that a great many people in this country had really made up their minds, I think, that that class of water filters could be operated with merely the water used in washing, and without any form of air washing. I think that led to the construction of the plant at Cincinnati, where it is contemplated to wash filters without any agitation. At Little Falls, however, after six months washing with water only, the filters so operated began to show a serious falling off in bacterial efficiency, and it was necessary to resume the air agitation to secure a proper efficiency.

This tends to prove that it is going to be almost impossible to maintain a proper bacterial efficiency on almost any character of water without some agitation of the sand. That may be rather a broad conclusion to reach, but certainly if that is true on the class of water at Little Falls, containing practically no suspended matter, it is going to be true on waters in the west. While a filter under test may be operated to its highest efficiency, you cannot tell exactly what is going to happen afterwards, and if it is necessary to use some form of agitation on water which is turbid, any fault in the operation is going to decrease the efficiency in the settling basins and render an efficient wash even more necessary.

One other point I will mention; that is the use of sulphate of copper as a coagulant. That the use of sulphate of iron and lime has, to a certain degree, superceded sulphate of alumina is due mainly to the fact that the American Steel & Wire Company had sixty or sev-

enty thousand tons of sulphate of iron as a by-product, which was being wasted. They saw the possibility of marketing that product for water purification, and came to the conclusion that if a standard product was turned out so that the operators of a filter plant could know that they were going to get the same composition of sulphate of iron in one order that they had received previously, a market for this by-product could be obtained. So for two or three years sulphate of iron with lime, has been largely used, mainly on account of its cheapness. You have probably seen, during the last two or three years, the Government's experiments in the use of sulphate of copper in the case of algae waters. It has been found, also, that sulphate of copper will practically eliminate the pathogenic germs. The manner in which the Government used that has been very crude. They have taken a bag of sulphate of copper and fastened it to a row boat, trailing it through a stream or reservoir, and after a certain time the algae growths have been eliminated and the pathogenic germs also.

That method, of course, was unsatisfactory because they had no way of controlling the amount of copper fed into the water. There is also the element of time against it, not because the action of sulphate of copper is not instantaneous, but because it took so long for the sulphate to get in contact with all the water.

The management of the American Steel & Wire Company conceived a brilliant idea. In making up their sulphate of iron coagulant, while the sulphate of iron was still in liquid state, they mixed with it about 1% of sulphate of copper, and crystallized the mixture; so that the sulphate of iron coagulant contains about 1% of sulphate of copper. You there get the two treatments in one. There is no additional trouble, to mix up and inject the sulphate of copper in the water, because that is included in the sulphate of iron, and it is an easy matter to control the amount of sulphate of copper fed to the water. The main ingenuity of their discovery was simply this: the sulphate of copper will coagulate with caustic lime in the same way as sulphate of iron. The gelatine coating formed on the filter beds with this combined sulphate of copper and sulphate of iron contains, therefore, always 1% of sulphate of copper. All the water, therefore, passes through the sulphate of copper. The chemical action of the copper is instantaneous and has resulted in the absolute elimination of the pathogenic germs. This is a very remarkable phase of the mechanical filter. In this way one is able to eliminate absolutely the disease bearing qualities of a water supply, irrespective of its character. It has been customary in filtration contracts to make a guaranty of percentage removal. While it is praiseworthy to remove 98% bacteria in water supply, you are always subject to the criticism that, while the chances of infection are reduced by the amount of the per cent. removed, they are not eliminated, and the filter plants, operating on a water which contains only 1,000 and another water containing 100,000 bacteria per

cubic centimeter, does not give to the consumer a water which is equally pure in one case as it is in the other, if you cannot eliminate the pathogenic germs. This system of combined coagulant was first tried at Anderson, Ind. At the time the experiments were first made, and at which were present several representatives of the Government, the filter was only removing about 90% of the bacteria. Those defects, however, were subsequently corrected; but during that time the filter system was absolutely removing all the pathogenic germs. This was also true of the process when tried in the plant at Marietta, Ohio. If the experience which has been at Anderson, Ind., and Marietta, Ohio, is going to prove equally true in other cases, it is certainly a remarkable advance in one phase of mechanical filtration.

*W. L. Abbott,* M. W. S. E.—I would like to ask why it should be necessary to agitate the filter with air at all. It appears to me that as the method of washing the filter bed is to agitate, loosen and remove the impurities by reverse current, why would it not be better to use a large volume of water to raise the sand of the filter bed and make it quite loose. In such case I do not see that air would be necessary or at all useful. It would, of course, take more water than where air is used, but a large volume of water in my mind could accomplish the same purpose.

*Mr. Denison*—I think possibly the process is not quite clear, and that you have not a clear idea as to just what office the filter performs. The theory is that the sand grains are scoured by the air and the water is used to carry off the rinsings. In the old Warren filters, they used merely enough water through the filter beds, to carry off the dirty water which was had from scouring the sand. They washed the filter with a mechanical rake which was made very heavy. They left just enough water through their sand bed to loosen it up, so they could revolve their agitator and scour their sand; the water was used merely to rinse the sand beds, after the scouring by the agitator, and that is really the feature of all forms of said agitation,—a scouring of the sand grains against each other.

*Mr. Abbott*—That is a conception of the process which I did not know of before. I understand from your explanation that the individual grains of sand are coated with slime which the reverse current of water would not remove, and the agitation of the bed is necessary to scrape the slime off of the individual grains of sand in the bed.

*Mr. Denison*—Of course if the sand grains were absolutely smooth it is probable that the sand bed could be washed effectively with merely wash water; in other words, there would be friction enough to carry off the dirt, but inasmuch as the sand grain is not perfectly smooth it needs a little more violent agitation than is to be had merely with the wash water.

*Walter Wagner,* M. W. S. E.—About the air wash: The action

of the air in washing a filter bed is not so much agitation but consists in breaking up the film or mud planked on top of the sand.

I am perfectly satisfied that a filter can be washed with water alone if a strong enough current is applied and if the raw water is not too muddy. But the possible strength of the water current is limited; it must not be so great as to carry the sand away with the wash water.

I have been in the past rather skeptical about air as an agitator being used to and familiar with mechanical agitation, I know that an agitator to be effective should agitate the sand. But if you observe the action of the air in passing through the sand you will notice that there is no agitation in the sand bed with the exception of the very surface of the same. The air passes through the sand as it would through a brick wall, without disturbing it, the sand remaining perfectly compact; but the surface, consisting of a blanket of all the accumulated impurities, is broken up in small particles by the air coming up through the sand, so that when afterwards the water is applied it can easily carry off finely broken up particles of sediment.

It was during a test in Indiana, when on account of some trouble with the air blower, for a time we discontinued the air wash, that I noticed after two or three days that the filters were not entirely clean after washing. Some little mud balls would form on top of the filter bed which were too heavy to be carried off by the water and would gradually work their way down into the filter bed. This formation of mud balls on very muddy waters is entirely prevented by the use of air.

I would like to make a few suggestions to those engineers present who are at times called upon to draw up specifications for filtration plants. The bacterial guarantees demanded, are generally based on a percentage of reduction, and in addition to this guarantee there is sometimes demanded a guarantee as to the cost of treatment; that is to say, a guarantee as to the amount of coagulent required. This I always consider an unfair demand, as the contractor has no means of knowing before hand the character of the water he will encounter at the time when an official test is made; and in my experience I do not know of any instance where a contractor has been made to suffer on this account. If it is not intended that this guarantee as to cost of treatment shall be enforced, it should never be demanded.

The factors which govern the efficiency of a filtration plant are now so well understood that there is no good reason why this class of work should not be treated like any other piece of engineering. The specifications should be confined to the design and to the character of workmanship and material.

*Mr. Mead*--On the question of guarantees I agree with Mr. Wagner perfectly, but I think the filter companies brought that matter entirely upon themselves. When arguing the question of the first cost, the statement has been made, "You can do this for so

much, and it will only cost so much to operate the filters." These guarantees have grown up entirely from that line of argument in favor of filtration, that you can filter the water for about so much. In any properly designed system it is not necessary to furnish a guarantee as to cost or efficiency and I do not think it is necessary to ask a guarantee except for good work. I think the filter companies are to blame for that requirement guarantee.

*J. W. Alvord*, M. W. S. E.—Perhaps, after all, the technical explanation we have heard, which has been very interesting, it might be interesting to ask why do we filter water? My first filter problem arose in 1884. And while I obtained a great deal of valuable information upon the subject, it did not succeed in convincing me at that time that we should filter the water. That was an early date, however. In that very year a German scientist had isolated the bacilli of typhoid fever. Out of his discovery grew the real demand for filtering water, and coming in company with that demand has come the desire of the public to have a clearer and more attractive water, that has been a secondary consideration Our real desire has been and will be to filter water to enable us to avoid disease, and the avoidance of disease is the supreme test of any filter plant. Out of the abundance of our resources has come, however, a great deal of overconfidence in our ability to continuously and absolutely accomplish this result. I am speaking particularly of the point raised by Mr. Mead in the operation of filter plants. I recall the first filter plant I ever saw. It was a slow sand filter plant of the Berlin (Germany) Water Works which I visited and examined in 1888. I was much interested in it, and carried away the idea that there was a plant doing exceptional work, but at that time it would appear that the supreme test of disease immunity was not being fulfilled, typhoid was prevalent, was epidemic, in fact at that time. It was found out later that ice had formed on the filter and interferred with the surface of the sand to such an extent as to allow the raw water at times to pass through the filter without the removal of pathogenic germs.

I was compelled to point out in testimony in the St. Louis pollution case some time ago, that no less than twelve well known instances have occurred where first class, well designed filter plants intended to filter water to the highest degree of purity, have, nevertheless, through defective design, carelessness, overconfidence or ignorance permitted serious epidemics of preventable disease to occur. This has come about in most cases, by an overconfidence in the efficiency of the design, and a lack of appreciation of the eternal vigilance necessary to operation; a natural feeling has arisen that a first class and well designed filter plant is of itself a permanent guarantee for all time. A tremendous responsibility rests upon the superintendent of the best designed filter plant; he must always guard the health and lives of the community every moment of the night or day, year in and year out, with ceaseless vigilance; especial-

ly is this true where he has polluted waters to deal with. And so it is, that there has come and is now upon us, the feeling among those who think, that filter plants are not the universal panacea that we have popularly supposed them to be. In my humble opinion we must cease trying to filter sewage water for drinking purposes. We must not attempt to take waters which are not potable and which are not presentable for human sustenance and endeavor to make a drinking water of them. I have at times expressed the somewhat empirical opinion that a naturally pure water supply warranted an expenditure from 50 to 100% more, in point of cost, over polluted waters with filtration added. And I see no reason as yet to alter this opinion.

CLOSURE.

*Mr. R. E. Milligan*—In answer to the remarks of Mr. Mead, it is true that I am and have been connected with the New York Continental Jewell Filtration Co., and it is because of the opportunities and personal observation afforded me through that connection that I venture to address the Western Society of Engineers on mechanical filtration and its development. My paper is not intended, however, to limit itself to any extent other than that bounded by my own experience and observation irrespective of manufacture or design. Neither of the large plants mentioned by Mr. Mead are completed at this writing; consequently their efficiency cannot be described by me.

I have, however, seen the plans of the proposed plant at Cincinnati, and see little if any deviation from the general types alluded to in my paper. The method of washing filter units by water alone under considerable pressure, and with considerable volume, is not novel, having been employed in the earliest mechanical filters, and the results are indicated in the remarks of Mr. Denison and Mr. Wagner. I take pleasure also in confirming Mr. Mead's statement, that control of mechanical filtration does not rest in the hands of the filter companies, nor do they claim that it does. Most engineers will, I think, agree with me that possession of patents covering the ingenuity of individuals either singly or collectively in connection with engineering devices, does not necessarily indicate a vicious attitude on the part of the possessor. Certainly it has the authority of the United States Government, and in my experience it has never been the practice in connection with mechanical filtration to use that possession for any other purpose than to prevent infringement of what is palpably the right of the possessor.

My contention really is, that notwithstanding the fact that no design has been withheld from the public and its engineers, no material change has resulted in increased efficiency thereby, and I conclude that if the last word on mechanical filtration has not been spoken, at least no material change has occurred either in design or efficiency.

Mr. Mead is quite correct in his warning as to the limitations of filtration and this leads me to speak of ozoniation as a possible adjunct to filtration, though no, development known to me would warrant its discussion in such a paper as this. Personally I am inclined to some such method as a further safeguard to secure a purified water simply from a badly polluted source.

Concerning the Danville filters the eastern chemist alluded to was employed to establish results, which he did, the results being unsatisfactory. A filter expert was employed to determine why apparently incongruous results existed and he was successful in his research, and I understand there has been no further occasion for his services. The construction of the Little Falls buildings was an economical engineering expedient, and after five years operation has elicited no unfavorable comment from the men in charge of the plant, and all parts of the filter units are readily accessible; more so indeed than any covered slow sand plant with which I am familiar. The question is one of expediency and expense, is my opinion.

My experience leads me into hearty accord with Mr. Mead in his statement as to the limitations of a coagulating or sedimentation basin, as well as to the necessity for intelligent operation, after a properly designed and constructed plant passes from the hands of the engineer and builder. I think, however, that in the case of the larger plants such superintendance is becoming more and more of a recognized necessity.

Mr. Wagner's explanation of the air wash is the correct one, in my judgment, and same is fully explained in my first paper on mechanical filtration read in 1902 before the Western Society of Engineers. Mr. Abbott must realize the compactness of a filter bed after several hours' use to understand the necessity of some additional force to break up this solid compact mass, other than water which tends to raise the bed as a whole and causes the bed to "crack" and open, offering an easy but somewhat useless escape for the incoming wash water. The air perforates the bed in all directions and offers many channels for the wash water rather than the few it forces for itself.

## SOME CHARACTERISTICS OF COAL AS AFFECTING PERFORMANCE WITH STEAM BOILERS.

W. L. Abbott, M. W. S. E.

*Presented, Sept. 5, 1906.*

### INTRODUCTORY.

About 90 per cent. of the steam generated in the large power houses of the central west is generated by the use of what is called screenings, as fuel. We have noticed that these screenings from mines in different districts differs from that from other mines in other districts, moderately in its chemical composition and laboratory heat value. We have also noticed that screenings from these same mines differ greatly from each other, in commercial value, when burned under a boiler.

For the purpose of determining, if possible, some simple rules by which the value of coal could be determined without a continuous boiler test going on in a power house, the Chicago Edison Company proposed a series of tests. Mr. Bement was placed in charge of these, and the results and conclusions given in this paper are drawn from his reports.

In general these tests were made to determine the effect of varying percentages of ash and of different grades of fineness upon the value of the coal. To determine the effect of fineness or size, a large sample of coal, amounting to 100 tons or more, was taken and screened through sieves of different mesh until we got several piles of coal, each of approximately uniform size, and with each of these samples, boiler tests were made. The results of these tests are shown in the diagram, Fig. 2, the upper curve indicating the horse power obtained, or the *capacity,* and the lower curve the *efficiency* derived from these various sizes. It will be observed that the grade of coal nearest in size to a mesh ¾ in. square gave the highest capacity, and at the same time the greatest efficiency. Th reason for the variation in the values of the different sizes is partially explained in the table preceding Fig. 3, which shows that the smaller sizes carry a greater amount of ash, but it is not ash alone which accounts for all of the difference.

To further investigate the effect of size upon capacity and efficiency, a series of 62 tests on ordinary screening were analyzed, and the efficiencies and capacities which were obtained from these tests are plotted in diagrams, Figs. 4 and 5. A curious and unexpected result is shown. As might have been expected screenings having an average size of 1-10 in. or under, gave the lowest results. As the average size of the coal increased up to about 3-10 in., the efficiency and the horse-power increased with it. From that point.

as the coal became coarser, the efficiency dropped off until reaching a size something less than ½ in., from which point it again increased. A theory for the explanation of this is given in a paragraph following Fig. 5, but everyone is entitled to a guess on this as well as the author. One fact, however, is brought out, and it cannot be too strongly emphasized, that the presence of fine dust is a great source of trouble.

The expression "average size of the coal" means the size of screen mesh which will allow half of a sample to pass through it, and will retain half on top.

"Referring to Fig. 2, coal through an ¼ in. square screen produced only 108 horse-power, yet a size of fuel known in Illinois as No. 5 washed coal, which will pass through an ¼ in. round hole (a smaller aperature than the square opening) will produce as high as 600 horse-power under the same boiler."

It is probably true that if coal which contains so much dust that we would be unable to get one-half boiler capacity out of it, were put through a washer and freed from this objectionable fine dust only, not more than 3 per cent. of the combustible would be lost in the process. This would indicate that if the coal operator could free his coal from this 3 per cent. of dust, either by washing or, perhaps easier by fanning, he could vastly improve the quality of his coal at a very slight loss of 3 per cent. of the coal mined. In washing coal, as much as 10 or 15 per cent. of combustible matter is sometimes removed, to get rid of less than that per cent. of ash. The coal could be improved in quality nearly as much, by the simple expedient of removing 3 per cent. of dust, such as would go through a 20 mesh screen.

Another test not directly bearing on the value of the fuel was made to determine the efficiencies of fire beds of different thicknesses. As these tests were all made on chain grate stokers, it was an easy matter to regulate the thickness of the fire to a nicety. The results obtained are shown in the diagram Fig. 6, the upper curves indicating the horse-power obtained with two different sizes of coal. These curves show that by varying the thickness of fire you can obtain a greater or less capacity from the boilers, but the curves below that, showing the efficiency, indicate that, regardless of the thickness of the fire the efficiency remained the same.

When operating a chain grate stoker, about all the fireman can do is to regulate the thickness of the fire, but this diagram indicates that he is powerless in this case to regulate the efficiency of his apparatus. He can increase the horse power but cannot burn coal more economically. The conditions are fixed and he has no control over them.

To determine the effect of ash upon the value of fuel we conducted a series of tests upon a large and uniform lot of coal. A portion of this sample was carefully analyzed and tested in its natural condition as received from the mine. We then took another

portion of the original coal and into it mixed a known percentage of ash. This gave us a quality of coal similar to what was tested first, but containing more ash. This was tested. On the following day another lot was tested with a greater per cent. of ash added, and so on. The results are shown in the diagram, Fig. 3. In this diagram the solid curve indicates horse-power, and the curve with dashes indicates efficiency. The first test was made with coal containing something less than ten per cent. of ash, and successive tests with increasing amounts. When the ash content had been increased to 40 per cent. we could still burn the coal, and the coal would heat the water up to the boiling point, but it would not produce enough heat to make steam. Therefore, coal containing 40 per cent. of ash was absolutely valueless. This curve, Fig. 3, I consider the most interesting and satisfactory of any that we obtained during these tests. Those two curves—one of efficiency and one of capacity—are shown reproduced in Fig. 7, and the curve drawn through them which we have taken to indicate the value of the coal, because coal has one value in proportion to its efficiency and another in proportion to the boiler capacity that can be generated with it. Therefore with a curve drawn through the other two we may have the true indication of the commercial value of the coal. The scale on the left is drawn from 0 to 100, 100 being taken as a standard in coal having an ash of 12 per cent.

The object of these tests, as stated before, was to determine upon some simple rule or tabulation to fix the commercial value of coals. This curve indicates its value as affected by ash. To determine its value as affected by fineness we were not so successful. A diagram, Fig. 3, shows an attempt to get a curve of such values. For this purpose we took from our records of various tested samples their boiler efficiency values, together with the percentages which would go through a ¼ in. screen. These values are plotted in the diagram and while anyone might draw a curve through it, no two would draw a curve in the same direction.

On the opposite page, Fig. 11, is an attempt to get something through which we could plot a curve, but using a ½ in. screen as a standard; that effort was equally unsuccessful.

In Fig. 12 is shown another attempt, which is perhaps a little better. In this case a screen having ¼ in. round holes, which is about 60% of the value of a ¼ in. square screen was used and we obtained something which, with a little imagination, will warrant us in drawing a curve. The dotted line is the curve drawn, and it is all right except for four scattering tests, "toward the northeast corner." As the ash in these samples average 18 per cent., the curve was corrected to ash of 12% and the solid line drawn.

We now have two curves, one showing the effect of fineness and the other the effect of ash. These two curves were combined and tabulated as shown in table B, which purports to give the purchasing agent the information he wants. It shows the effect of varying

percentages of ash and the effect of varying degrees of fineness, and while we do not care to vouch for its correctness when applied to other coals, we will say freely that it is the best thing of the kind we have seen. If we were to go through this again we would probably select, instead of a screen having ¼ in. round holes, a screen having something like ⅛ in. round holes, for the reason that it shows better the percentage of the dust in the coal.

THE PAPER AS SENT OUT IN ADVANCE.

The capacity and efficiency obtained with a steam boiler is the result of many influences more or less variable in character, and for the purpose of studying some of these influences, certain experiments were conducted in which coal screenings were used, the results of which are presented in this paper.

The apparatus employed in the researches to be considered consisted of two Babcock & Wilcox boilers, one being fourteen tubes

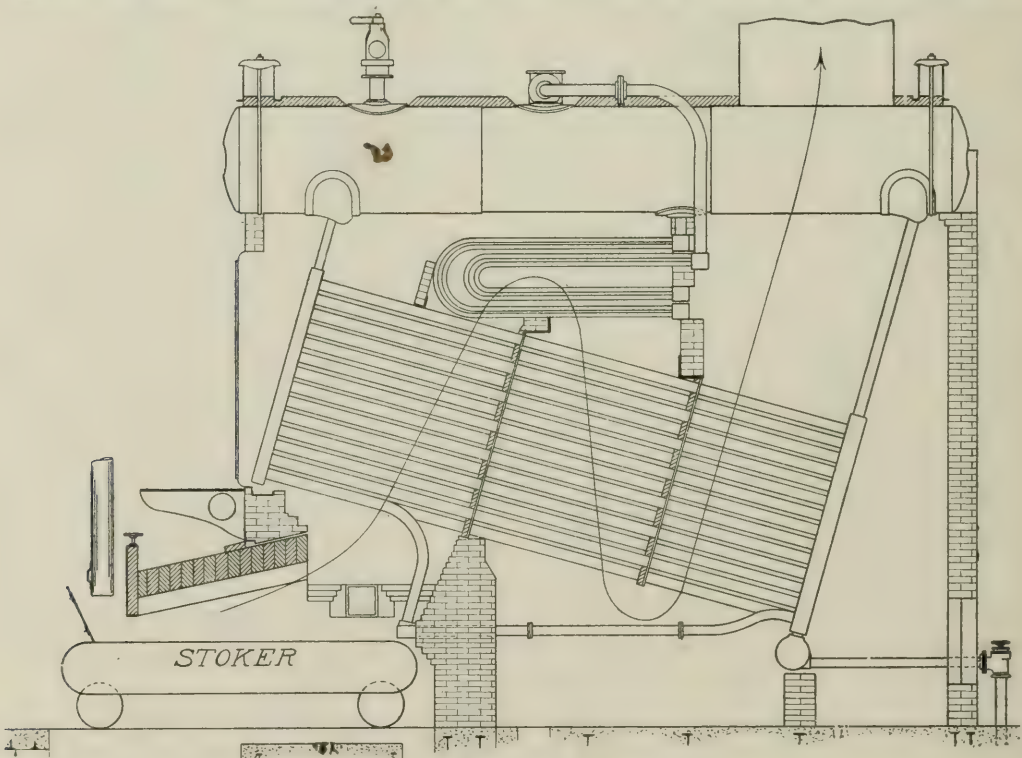



Fig. 1.

ELEVATION OF BOILER AND STOKER EMPLOYED IN THE EXPERIMENTS

high and eighteen wide, of approximately 5,000 sq. ft. of heating surface, fitted with a chain grate stoker of 75 sq. ft. in area, which discharged the gases of the fire from under an ignition arch 5 ft. long, immediately among the tubes of the boiler; this boiler was also fitted with a Babcock & Wilcox superheater having an approximate area of 1,000 sq. ft. The other apparatus employed in one of the series of tests differed only in sizes; its boiler was twelve tubes

high and sixteen wide, contained 4,000 sq. ft. of heating surface, provided with a superheater and served with a chain grate stoker of 66 sq. ft. in area. Fig. 1 is a sectional elevation of the larger boiler.

The experiments were for the purpose of studying the following features and their influence with the particular apparatus used, and are presented in the following order:

EFFECT ON CAPACITY AND EFFICIENCY DUE TO COAL OF DIFFERENT SIZES.

INFLUENCE OF ASH IN COAL ON CAPACITY AND EFFICIENCY.

EFFECT OF VARIATION IN SIZE OF COAL SCREENINGS.

RESULTS OF DIFFERENT THICKNESSES OF FIRE.

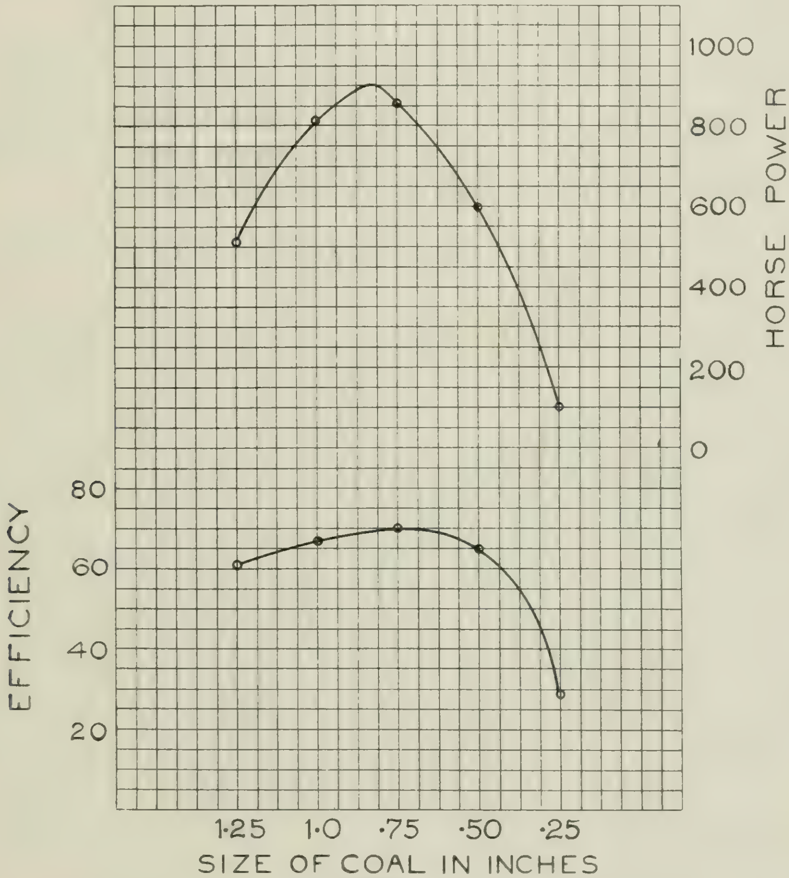



Fig. 2.

EFFECT PRODUCED IN STEAM GENERATION, BY COAL OF VARYING SIZES.

The experiments illustrated by the diagram (Fig. 2) consisted in the use of coal separated into various sizes by means of screens having the following square openings: 0.25, 0.50, 0.75, 1.0 and 1.25 inches. The coal was all from one lot, so that the different portions resulting from the screening process were necessarily the "same kind of coal," except that some portions were uniformly larger and others smaller, and that the smallest, on account of its size, was higher in ash. As shown by the curves of efficiency and capacity in the dia-

gram, five tests were made, each with a different size of coal. In all other respects, however, everything was equal; thus influencing conditions, except that due to size of coal, were constant. In this way, relative values for the feature studied were obtained as shown by the diagram.

It is well in this connection to give the percentage of ash in the dry coal of the various sizes.

| | *Square screens.* *Through.* | *Over.* | *Ash in Dry Coal.* |
|---|---|---|---|
| Size of coal in inches | 1.25 | 1.00 | 13.7 |
| " " " | 1.00 | 0.75 | 14.0 |
| " " " | 0.75 | 0.50 | 15.6 |
| " " " | 0.50 | 0.25 | 20.8 |
| " " " | 0.25 | 0.00 | 30.8 |

The high per cent. in the smallest size is not due to ash in the coal itself, but to the fact that all of the fine sized foreign matter separated from larger coal, or which comes from roof or floor of the mine, naturally finds its way into this smaller coal.

INFLUENCE OF ASH IN COAL ON CAPACITY AND EFFICIENCY.

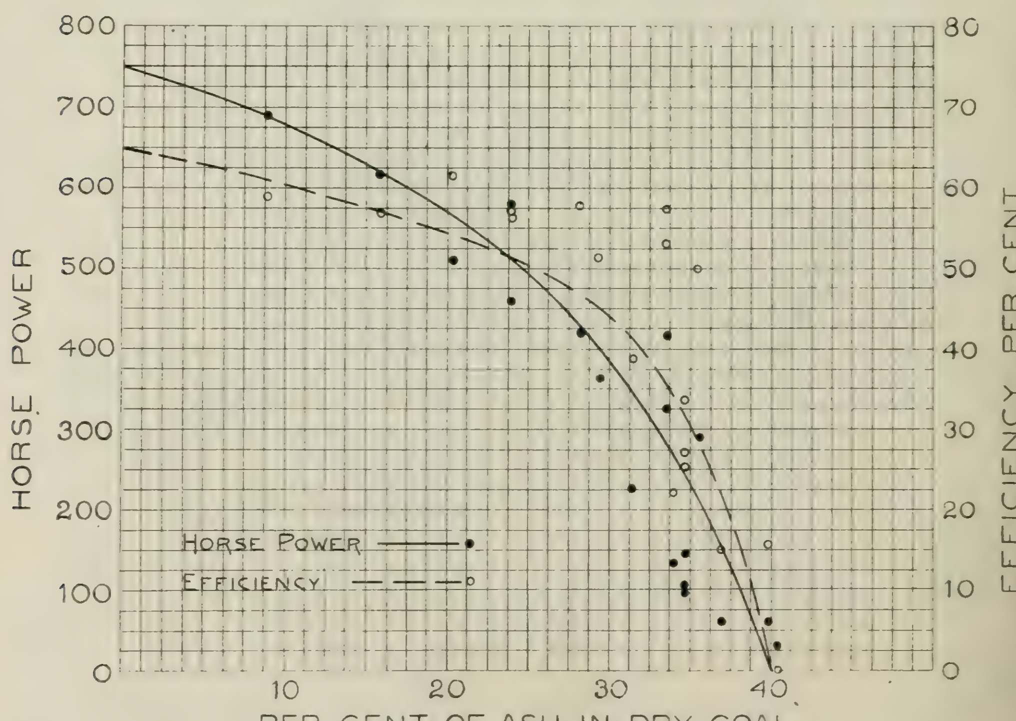



Fig. 3.

INFLUENCE OF VARYING PER CENTAGE OF ASH IN COAL.

This diagram (Fig. 3) gives results of eighteen tests made to determine the effect of varying quantities of ash associated with coal. One result of its presence is to reduce the heating power. owing to displacement of combustible matter. Therefore, in this

connection, ash may be considered as a dilutant, and if this was the only result of its presence, it would have no effect on heat efficiency secured through a boiler. A proportionately less amount of water would be evaporated by a pound of such mixture of ash and coal, of course, but efficiency would not be affected. If, however, ash acts in some other way as well, such as an obstruction to the combustion process, the effect of its presence is doubly harmful.

To insure that the result would not be affected by any influence other than that of the ash, special coal was used which came from the No. 7 seam, north of Marion in Williamson county, Ill. It was prepared in a Stewart washer and is known to the trade as No. 4 washed coal, a size made by passing over a screen having ¼ in. round openings, and through one having similar ½ in. openings. Its composition is represented by the following:

| | |
|---|---|
| Moist Coal: | |
| Moisture | 7.48 |
| Ash | 8.23 |
| B. T. U. | 12,191 |
| Dry Coal: | |
| Ash | 8.90 |
| B. T. U. | 13,176 |
| Pure Coal: | |
| B. T. U. | 14,463 |

The test indicated by the two points showing highest efficiency and capacity was made with coal just as it arrived, or in other words, was of the composition shown by the analysis. Beginning with the test of the second day, a quantity of refuse from the stoker ash pits was added to the coal to be used. This refuse was first weighed and the large pieces broken up, after which it was thoroughly mixed with the coal in the required proportion and increasing amounts were added in each test which followed. This fuel composition was, of course, weighed as used and a sample of it selected for analysis in the regular manner.

It appears from the diagram that useful effect from the fuel drops to zero with 40 per cent. of ash, notwithstanding the fact that the other 60 per cent. of the composition was pure coal. The fact should be emphasized, that although over half of the composition fed to the fire was fuel, it burned without producing any useful effect, for which there are two reasons; one, that on account of obstructed air supply through the fuel bed, incomplete combustion and escaping hydrocarbons carried away a portion of the heat, because the gases passed immediately among the tubes of the boiler. The other is, that owing to the presence of an excess of ash, the percentage of fuel on the rear portion of the grate is greatly reduced. On this account a larger proportion of the air passing through the fuel bed does not combine with the fuel, but enters the furnace as free air. As the prime function of a furnace is to heat the gases passing through it,

any increase in the amount of air entering the furnace without a corresponding increase in the amount of fuel burned must result in a lowering of the furnace temperature.

This lowering of temperature, besides making a long, smoky flame which reaches up among the boiler tubes and is there chilled to below the burning point, also reacts on the fuel bed, reducing the rate of combustion and still further increasing the adulteration of the furnace gases with free air. When the temperature of the furnace has been thus reduced to about 600° F. the boiler is unable to absorb any more heat than is necessary to make up for radiation losses.

It will be observed that the points on the diagram do not fall in symmetrical order. This is particularly true of ash percentages of about 34, which may be explained by the refuse used in these tests being probably of a more fusible character than with others. These tests with the ash composition were made with the smaller boiler above mentioned.

EFFECT OF VARIATION IN SIZE OF COAL SCREENINGS.

In Illinois and Indiana coal not sold as mine run is separated largely as lump and screenings, and such screenings furnish about 90 per cent. of the stoker fuel used in Illinois.

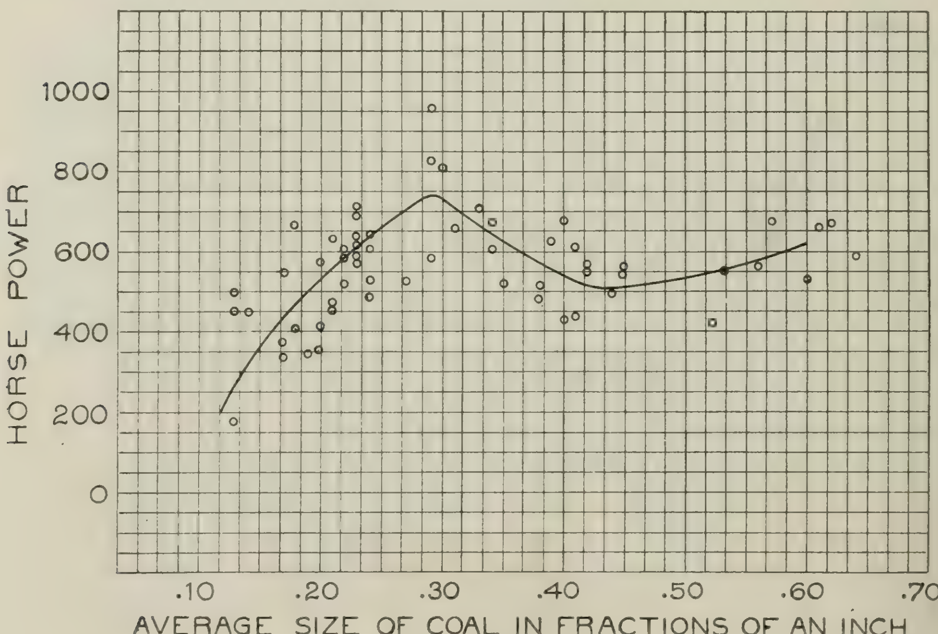



Fig. 4.

EFFECT OF SIZE IN COAL SCREENINGS ON CAPACITY PRODUCED.

The diagrams (Figs. 4 and 5) illustrate the result of sixty-two tests. With each the size of coal as measured by screens with square openings ranging in dimensions from 0.25 to 1.50 ins., advancing by 0.25 in., and the average sizes of coal as shown at the base of the diagrams, were calculated from sizing tests made with these screens.

and represent the dimension in fractions of an inch of openings in a screen which would allow one-half of the coal to pass through and the other half to go over the screen, and it is this that is designated as its average size.

In diagrams, Fig. 4 shows the effect produced on horse-power output owing to this variation in size of the coal, and Fig. 5 illustrates the resulting efficiency from the same cause and for the same tests.

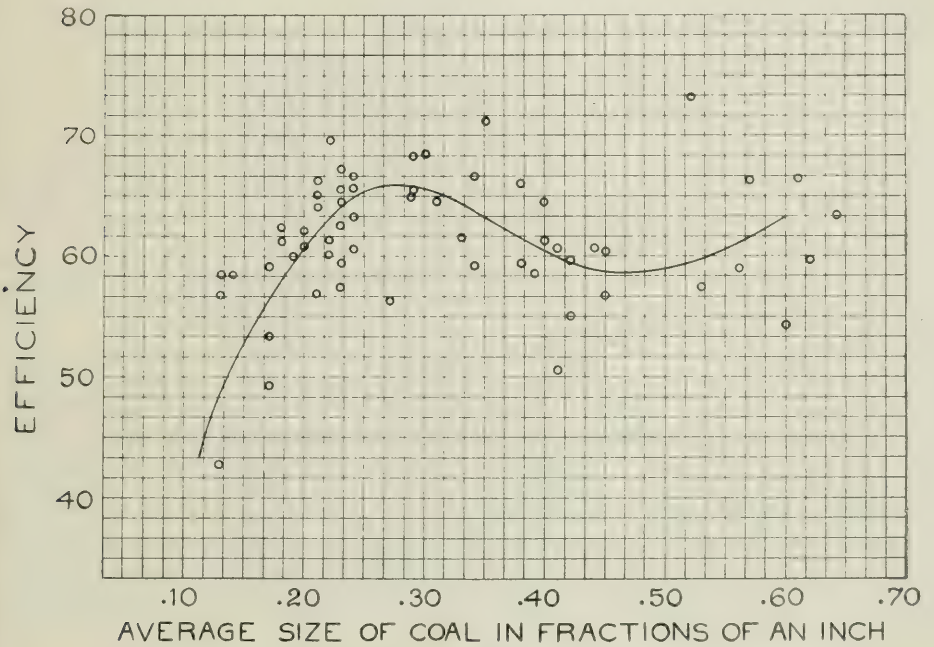



Fig. 5.

EFFECT OF SIZE OF COAL SCREENINGS ON EFFICIENCY PRODUCED.

The curves for both efficiency and capacity drop midway between the tests with both small and large coal. This is a peculiarity which may be explained as follows: Performance becomes better as the size of coal increases, until a point is reached when the quantity of large pieces becomes so great that there is not enough fine material to properly close the interstices between, with the result that performance drops off, due to excess of air, until a condition is reached when all of the pieces of fuel approach uniformity, when owing to greater agreement in size, they fit together better, and in a measure produce a homogeneous mass similar to that secured by the fine dust filling the spaces in the fuel bed in the first case.

The presence of fine dust in excess is a great and important source of trouble. Referring to Fig. 2, coal through an 0.25 in. square screen produced only 108 horse-power, yet a size of fuel known in Illinois as No. 5 washed coal, which will pass through an 0.25 in. round hole (a smaller aperature than the square opening) will produce as high as 600 horse-power under the same boiler. It is true that the lower ash content of the washed coal has a consider-

able influence, but this is offset by the larger size of the square screen as against the round one.

To arrive at a better understanding of the physical make-up of these two characters of fuel, tests were made of the dust of each, using that quantity which would pass through a 20-mesh screen, with the results shown in Table A.

## TABLE A.

### QUANTITY AND SIZE OF COAL DUST BELOW 20-MESH SCREEN.

Per Cent. of Different Sizes.

| Dust Sample | Through 20 and over 40 | Through 40 and over 60 | Through 60 and over 80 | Through 80 and over 100 | Through 100 |
|---|---|---|---|---|---|
| No. 5 washed | 63.36 | 16.78 | 6.51 | 2.93 | 10.42 |
| Duff through ¼ in. square screen | 46.10 | 13.87 | 8.18 | 3.84 | 28.01 |
| Average of five tests from ordinary screenings | 48.50 | 13.78 | 7.57 | 4.38 | 25.74 |

The quantity of the extremely fine dust through the 100-mesh screen is shown to be almost three times as much in the unwashed as with the washed coal. The third line of the table is an average from five tests taken from different lots of screenings, and it shows an approximate agreement with the quantities from the duff through the ¼ in. square screen, from which it follows that the presence of the fine dust has an enormous influence on the burning of the fuel.

### RESULT OF DIFFERENT THICKNESSES OF FIRE.

An excess of air accompanies a thin fire, and because of it, efficiency produced through the boiler is affected. On the other hand, a thick fire reduces the excess of air, but increases the volume of hydrocarbon gases which leave the surface, or in other words, makes more smoke. If a furnace is located between the boiler and stoker, these gases will be burned, otherwise they will largely escape among the tubes of the boiler as they did in this case. Therefore. under these conditions, a thin fire increases the loss due to excess of air, but decreases that due to smoke and incomplete combustion. On the other hand, a thick fire reduces the excess of air, but increases the smoke and escaping combustible gas, and so the best thickness of fire may be a matter of importance. With this type of boiler of a height of nine tubes when served with chain grate stokers discharging immediately among the tubes, it is always most economical to produce as large a volume of smoke as possible with the coal being used. With boilers of fourteen tubes in height, the conditions are different, because such boilers are more efficient.

With an ideal boiler the final temperature would be the same as the atmosphere, therefore an unlimited excess of air could be used

without causing heat loss. No practical boiler can, of course, be an ideal one, but the Babcock & Wilcox type of fourteen tubes high approaches much nearer to it than does one of nine high, and for that reason is more efficient, and in this connection is quite unique as Fig. 6 will show.

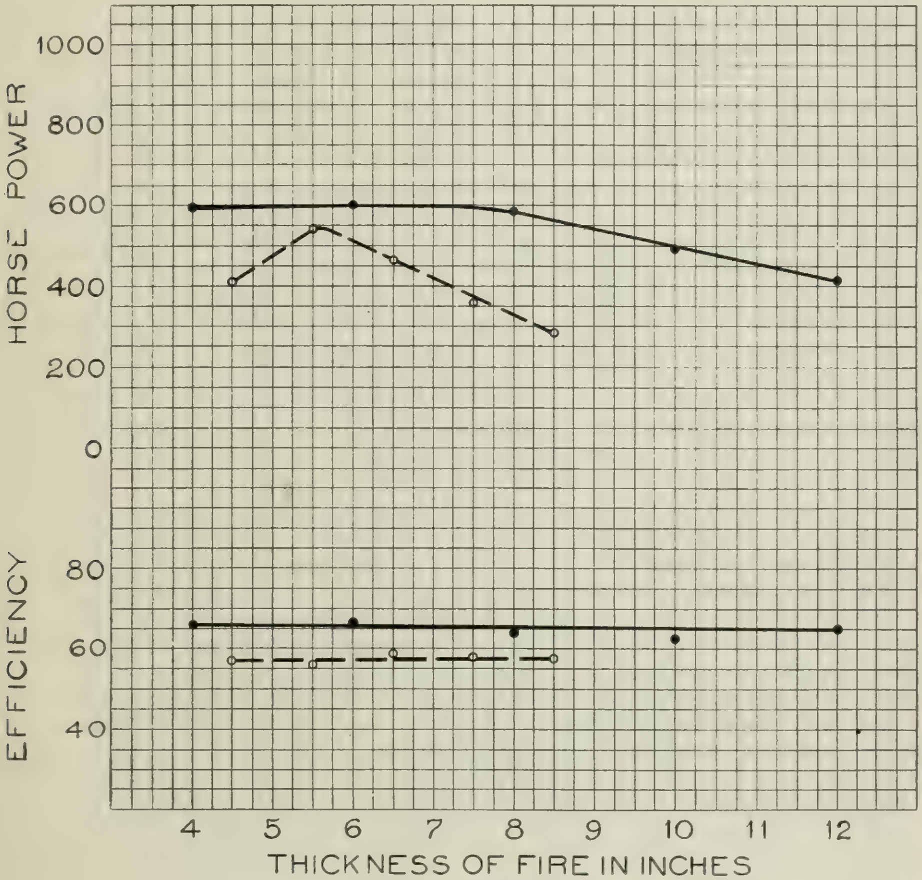



Fig. 6.

SHOWING UNIFORM HEAT EFFICIENCY WITH VARYING THICKNESS OF FIRE.

The curves of efficiency in this diagram illustrate a constant heat efficiency produced through the boiler for a full working range in thickness of fire, insuring not only maximum excess of air, but incomplete combustion loss as well, yet efficiency remained uniform. and the only opportunity for the "skillful" and "intelligent" fireman is in selecting that thickness best suited to capacity requirements.

The coal used in these two series of tests was very uniform in size and ash content, and for these reasons was well suited to the purpose of the experiments. In the series with thickness of fire, from 4.5 to 8.5 inches, what is known as No. 5 washed coal was used, a size which passes through a screen having round openings 0.25 in. diameter. With the other series and a larger range in thickness, washed screenings were employed.

TABLE SHOWING VALUE OF SCREENINGS.

Table B. gives values in one figure for screenings containing different percentages of ash, and of variation in size as measured by that portion passing through a 0.25 in. round screen. The following detailed statement explains how this table was prepared.

The value of coal screenings is affected by four variables, which are heating power, moisture, ash and size of the pieces of coal. Heating power in Illinois and Indiana of the pure coal—in other words, free from ash and moisture, the real coal—ranges from 13,800 as the minimum to a maximum of 14,500 B. T. U. per pound, and moisture from about 9 to 14 per cent. These two characteristics, however, are of minimum importance, as either can affect the result by only a comparatively small amount. With the other two features, amount of ash and size of the pieces, each may exert an influence of such moment that they cause the fuel to be valueless. Thus, in fuel inspection service it may be necessary to test only the latter characteristics, therefore table B. is based on variation in per cent. of ash and on size of the coal, moisture and heating power being assumed as constant.

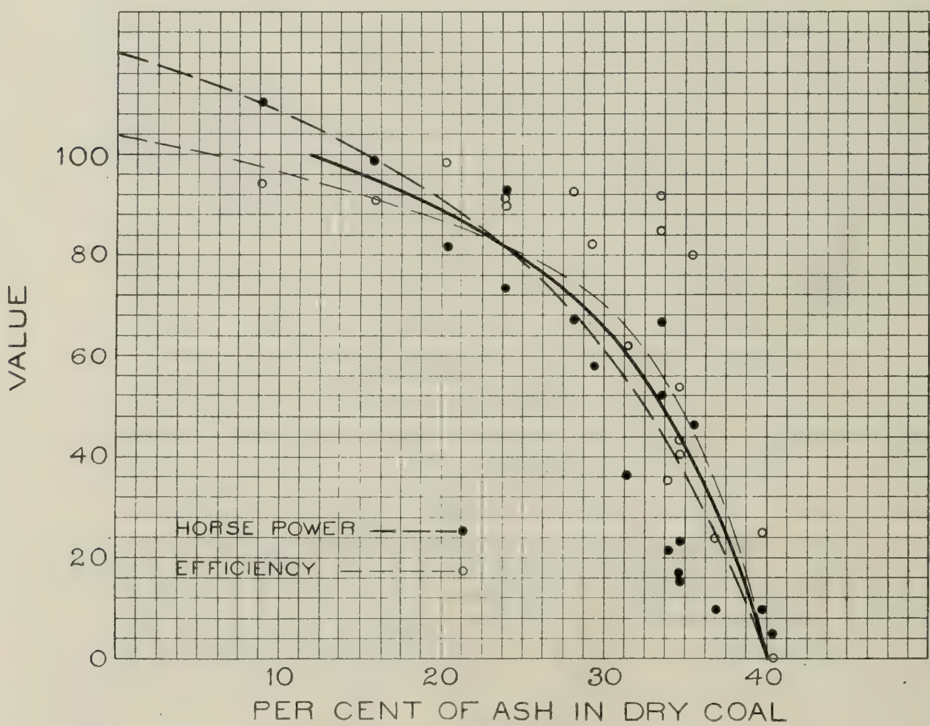



Fig. 7.

The fuel in service under a boiler produces two results, one of efficiency and the other of capacity, and capacity, or in other words, quantity of steam produced, is a matter of great importance. Therefore, if these two effects may be averaged and treated as a single value, the problem is much simplified.

## Percent of Ash in Dry Coal

Percentage of Coal through 1/4 inch Round Screen

| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 100 | 99 | 98 | 96 | 95 | 94 | 92 | 91 | 89 | 88 | 86 | 84 | 82 | 80 | 78 | 76 | 73 | 70 | 67 | 63 | 58 | 53 | 48 | 42 | 35 | 28 | 20 | 10 | 0 |
| 32 | 98 | 97 | 96 | 94 | 93 | 92 | 90 | 89 | 87 | 86 | 84 | 82 | 80 | 78 | 76 | 74 | 71 | 68 | 65 | 61 | 56 | 51 | 46 | 40 | 33 | 26 | 18 | 8 | |
| 33 | 96 | 95 | 94 | 92 | 91 | 90 | 88 | 87 | 85 | 84 | 82 | 80 | 78 | 76 | 74 | 72 | 69 | 66 | 63 | 59 | 54 | 49 | 44 | 38 | 31 | 24 | 16 | 5 | |
| 34 | 94 | 93 | 92 | 90 | 89 | 88 | 86 | 85 | 83 | 82 | 80 | 78 | 76 | 74 | 72 | 70 | 67 | 64 | 61 | 57 | 52 | 47 | 42 | 36 | 29 | 22 | 14 | 4 | |
| 35 | 93 | 92 | 91 | 89 | 88 | 87 | 85 | 84 | 82 | 81 | 79 | 77 | 75 | 73 | 71 | 69 | 66 | 63 | 60 | 56 | 51 | 46 | 41 | 35 | 28 | 21 | 13 | 3 | |
| 36 | 91 | 90 | 89 | 87 | 86 | 85 | 83 | 82 | 80 | 79 | 77 | 75 | 73 | 71 | 69 | 67 | 64 | 61 | 58 | 54 | 49 | 44 | 39 | 33 | 26 | 19 | 11 | 1 | |
| 37 | 90 | 89 | 88 | 86 | 85 | 84 | 82 | 81 | 79 | 78 | 76 | 74 | 72 | 70 | 68 | 66 | 63 | 60 | 57 | 53 | 48 | 43 | 38 | 32 | 25 | 18 | 10 | | |
| 38 | 88 | 87 | 86 | 84 | 83 | 82 | 80 | 79 | 77 | 76 | 74 | 72 | 70 | 68 | 66 | 64 | 61 | 58 | 55 | 51 | 46 | 41 | 36 | 30 | 23 | 16 | 8 | | |
| 39 | 87 | 86 | 85 | 83 | 82 | 81 | 79 | 78 | 76 | 75 | 73 | 71 | 69 | 67 | 65 | 63 | 60 | 57 | 54 | 50 | 45 | 40 | 35 | 29 | 22 | 15 | 7 | | |
| 40 | 85 | 84 | 83 | 81 | 80 | 79 | 77 | 76 | 74 | 73 | 71 | 69 | 67 | 65 | 63 | 61 | 58 | 55 | 52 | 48 | 43 | 38 | 33 | 27 | 20 | 13 | 5 | | |
| 41 | 83 | 82 | 81 | 79 | 78 | 77 | 75 | 74 | 72 | 71 | 69 | 67 | 65 | 63 | 61 | 59 | 56 | 53 | 50 | 46 | 41 | 36 | 31 | 25 | 18 | 11 | 3 | | |
| 42 | 82 | 81 | 80 | 78 | 77 | 76 | 74 | 73 | 71 | 70 | 68 | 66 | 64 | 62 | 60 | 58 | 55 | 52 | 49 | 45 | 40 | 35 | 30 | 24 | 17 | 10 | 2 | | |
| 43 | 80 | 79 | 78 | 76 | 75 | 74 | 72 | 71 | 69 | 68 | 66 | 64 | 62 | 60 | 58 | 56 | 53 | 50 | 47 | 43 | 38 | 33 | 28 | 22 | 15 | 8 | | | |
| 44 | 78 | 77 | 76 | 74 | 73 | 72 | 70 | 69 | 67 | 66 | 64 | 62 | 60 | 58 | 56 | 54 | 51 | 48 | 45 | 41 | 36 | 31 | 26 | 20 | 13 | 6 | | | |
| 45 | 77 | 76 | 75 | 73 | 72 | 71 | 69 | 68 | 66 | 65 | 63 | 61 | 59 | 57 | 55 | 53 | 50 | 47 | 44 | 40 | 35 | 30 | 25 | 19 | 12 | 5 | | | |
| 46 | 75 | 74 | 73 | 71 | 70 | 69 | 67 | 66 | 64 | 63 | 61 | 59 | 57 | 55 | 53 | 51 | 48 | 45 | 42 | 38 | 33 | 28 | 23 | 17 | 10 | 3 | | | |
| 47 | 74 | 73 | 72 | 70 | 69 | 68 | 66 | 65 | 63 | 62 | 60 | 58 | 56 | 54 | 52 | 50 | 47 | 44 | 41 | 37 | 32 | 27 | 22 | 16 | 9 | 2 | | | |
| 48 | 72 | 71 | 70 | 68 | 67 | 66 | 64 | 63 | 61 | 60 | 58 | 56 | 54 | 52 | 50 | 48 | 45 | 42 | 39 | 35 | 30 | 25 | 20 | 14 | 7 | | | | |
| 49 | 71 | 70 | 69 | 67 | 66 | 65 | 63 | 62 | 60 | 59 | 57 | 55 | 53 | 51 | 49 | 47 | 44 | 41 | 38 | 34 | 29 | 24 | 19 | 13 | 6 | | | | |
| 50 | 69 | 68 | 67 | 65 | 64 | 63 | 61 | 60 | 58 | 57 | 55 | 53 | 51 | 49 | 47 | 45 | 42 | 39 | 36 | 32 | 27 | 22 | 17 | 11 | 4 | | | | |
| 51 | 67 | 66 | 65 | 63 | 62 | 61 | 59 | 58 | 56 | 55 | 53 | 51 | 49 | 47 | 45 | 43 | 40 | 37 | 34 | 30 | 25 | 20 | 15 | 9 | 2 | | | | |
| 52 | 66 | 65 | 64 | 62 | 61 | 60 | 58 | 57 | 55 | 54 | 52 | 50 | 48 | 46 | 44 | 42 | 39 | 36 | 33 | 29 | 24 | 19 | 14 | 8 | 1 | | | | |
| 53 | 64 | 63 | 62 | 60 | 59 | 58 | 56 | 55 | 53 | 52 | 50 | 48 | 46 | 44 | 42 | 40 | 37 | 34 | 31 | 27 | 22 | 17 | 12 | 6 | | | | | |
| 54 | 62 | 61 | 60 | 58 | 57 | 56 | 54 | 53 | 51 | 50 | 48 | 46 | 44 | 42 | 40 | 38 | 35 | 32 | 29 | 25 | 20 | 15 | 10 | 4 | | | | | |
| 55 | 61 | 60 | 59 | 57 | 56 | 55 | 53 | 52 | 50 | 49 | 47 | 45 | 43 | 41 | 39 | 37 | 34 | 31 | 28 | 24 | 19 | 14 | 9 | 3 | | | | | |
| 56 | 59 | 58 | 57 | 55 | 54 | 53 | 51 | 50 | 48 | 47 | 45 | 43 | 41 | 39 | 37 | 35 | 32 | 29 | 26 | 22 | 17 | 12 | 7 | 1 | | | | | |
| 57 | 58 | 57 | 56 | 54 | 53 | 52 | 50 | 49 | 47 | 46 | 44 | 42 | 40 | 38 | 36 | 34 | 31 | 28 | 25 | 21 | 16 | 11 | 6 | | | | | | |
| 58 | 56 | 55 | 54 | 52 | 51 | 50 | 48 | 47 | 45 | 44 | 42 | 40 | 38 | 36 | 34 | 32 | 29 | 26 | 23 | 19 | 14 | 9 | 4 | | | | | | |
| 59 | 54 | 53 | 52 | 50 | 49 | 48 | 46 | 45 | 43 | 42 | 40 | 38 | 36 | 34 | 32 | 30 | 27 | 24 | 21 | 17 | 12 | 7 | 2 | | | | | | |
| 60 | 53 | 52 | 51 | 49 | 48 | 47 | 45 | 44 | 42 | 41 | 39 | 37 | 35 | 33 | 31 | 29 | 26 | 23 | 20 | 16 | 11 | 6 | 1 | | | | | | |
| 61 | 51 | 50 | 49 | 47 | 46 | 45 | 43 | 42 | 40 | 39 | 37 | 35 | 33 | 31 | 29 | 27 | 24 | 21 | 18 | 14 | 9 | 4 | | | | | | | |
| 62 | 49 | 48 | 47 | 45 | 44 | 43 | 41 | 40 | 38 | 37 | 35 | 33 | 31 | 29 | 27 | 25 | 22 | 19 | 16 | 12 | 7 | 2 | | | | | | | |
| 63 | 48 | 47 | 46 | 44 | 43 | 42 | 40 | 39 | 37 | 36 | 34 | 32 | 30 | 28 | 26 | 24 | 21 | 18 | 15 | 11 | 6 | 1 | | | | | | | |
| 64 | 46 | 45 | 44 | 42 | 41 | 40 | 38 | 37 | 35 | 34 | 32 | 30 | 28 | 26 | 24 | 22 | 19 | 16 | 13 | 9 | 4 | | | | | | | | |
| 65 | 45 | 44 | 43 | 41 | 40 | 39 | 37 | 36 | 34 | 33 | 31 | 29 | 27 | 25 | 23 | 21 | 18 | 15 | 12 | 8 | 3 | | | | | | | | |
| 66 | 43 | 42 | 41 | 39 | 38 | 37 | 35 | 34 | 32 | 31 | 29 | 27 | 25 | 23 | 21 | 19 | 16 | 13 | 10 | 6 | 1 | | | | | | | | |
| 67 | 41 | 40 | 39 | 37 | 36 | 35 | 33 | 32 | 30 | 29 | 27 | 25 | 23 | 21 | 19 | 17 | 14 | 11 | 8 | 4 | | | | | | | | | |
| 68 | 40 | 39 | 38 | 36 | 35 | 34 | 32 | 31 | 29 | 28 | 26 | 24 | 22 | 20 | 18 | 16 | 13 | 10 | 7 | 3 | | | | | | | | | |
| 69 | 38 | 37 | 36 | 34 | 33 | 32 | 30 | 29 | 27 | 26 | 24 | 22 | 20 | 18 | 16 | 14 | 11 | 8 | 5 | 1 | | | | | | | | | |
| 70 | 37 | 36 | 35 | 33 | 32 | 31 | 29 | 28 | 26 | 25 | 23 | 21 | 19 | 17 | 15 | 13 | 10 | 7 | 4 | | | | | | | | | | |
| 71 | 35 | 34 | 33 | 31 | 30 | 29 | 27 | 26 | 24 | 23 | 21 | 19 | 17 | 15 | 13 | 11 | 8 | 5 | 2 | | | | | | | | | | |
| 72 | 33 | 32 | 31 | 29 | 28 | 27 | 25 | 24 | 22 | 21 | 19 | 17 | 15 | 13 | 11 | 9 | 6 | 3 | | | | | | | | | | | |
| 73 | 32 | 31 | 30 | 28 | 27 | 26 | 24 | 23 | 21 | 20 | 18 | 16 | 14 | 12 | 10 | 8 | 5 | 2 | | | | | | | | | | | |
| 74 | 30 | 29 | 28 | 26 | 25 | 24 | 22 | 21 | 19 | 18 | 16 | 14 | 12 | 10 | 8 | 6 | 3 | | | | | | | | | | | | |
| 75 | 28 | 27 | 26 | 24 | 23 | 22 | 20 | 19 | 17 | 16 | 14 | 12 | 10 | 8 | 6 | 4 | 1 | | | | | | | | | | | | |
| 76 | 27 | 26 | 25 | 23 | 22 | 21 | 19 | 18 | 16 | 15 | 13 | 11 | 9 | 7 | 5 | 3 | | | | | | | | | | | | | |
| 77 | 25 | 24 | 23 | 21 | 20 | 19 | 17 | 16 | 14 | 13 | 11 | 9 | 7 | 5 | 3 | 1 | | | | | | | | | | | | | |
| 78 | 24 | 23 | 22 | 20 | 19 | 18 | 16 | 15 | 13 | 12 | 10 | 8 | 6 | 4 | 2 | | | | | | | | | | | | | | |
| 79 | 22 | 21 | 20 | 18 | 17 | 16 | 14 | 13 | 11 | 10 | 8 | 6 | 4 | 2 | | | | | | | | | | | | | | | |
| 80 | 20 | 19 | 18 | 16 | 15 | 14 | 12 | 11 | 9 | 8 | 6 | 4 | 2 | | | | | | | | | | | | | | | | |
| 81 | 19 | 18 | 17 | 15 | 14 | 13 | 11 | 10 | 8 | 7 | 5 | 3 | 1 | | | | | | | | | | | | | | | | |
| 82 | 17 | 16 | 15 | 13 | 12 | 11 | 9 | 8 | 6 | 5 | 3 | 1 | | | | | | | | | | | | | | | | | |
| 83 | 16 | 15 | 14 | 12 | 11 | 10 | 8 | 7 | 5 | 4 | 2 | | | | | | | | | | | | | | | | | | |
| 84 | 14 | 13 | 12 | 10 | 9 | 8 | 6 | 5 | 3 | 2 | | | | | | | | | | | | | | | | | | | |
| 85 | 12 | 11 | 10 | 8 | 7 | 6 | 4 | 3 | 1 | | | | | | | | | | | | | | | | | | | | |
| 86 | 11 | 10 | 9 | 7 | 6 | 5 | 3 | 2 | | | | | | | | | | | | | | | | | | | | | |
| 87 | 9 | 8 | 7 | 5 | 4 | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| 88 | 7 | 6 | 5 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 89 | 6 | 5 | 4 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 90 | 4 | 3 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 91 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 92 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 93 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

COAL VALUES FOR SCREENINGS

Table B.

Inspection of diagrams Figs. 4 and 5 shows that resulting capacity and efficiency are approximately the same, and that the condition of fuel which results in a high efficiency also produces large capacity. This makes it possible to assign two values to the fuel, one applying to ash content, the other to its size, each of these values embracing efficiency and capacity as a unit.

In placing the effect due to ash in shape for use in preparation of table B., diagram Fig. 7, which is a reproduction of Fig. 3, has a heavy curve drawn midway between those of efficiency and capacity. This average curve represents the value of the fuel as far as ash is

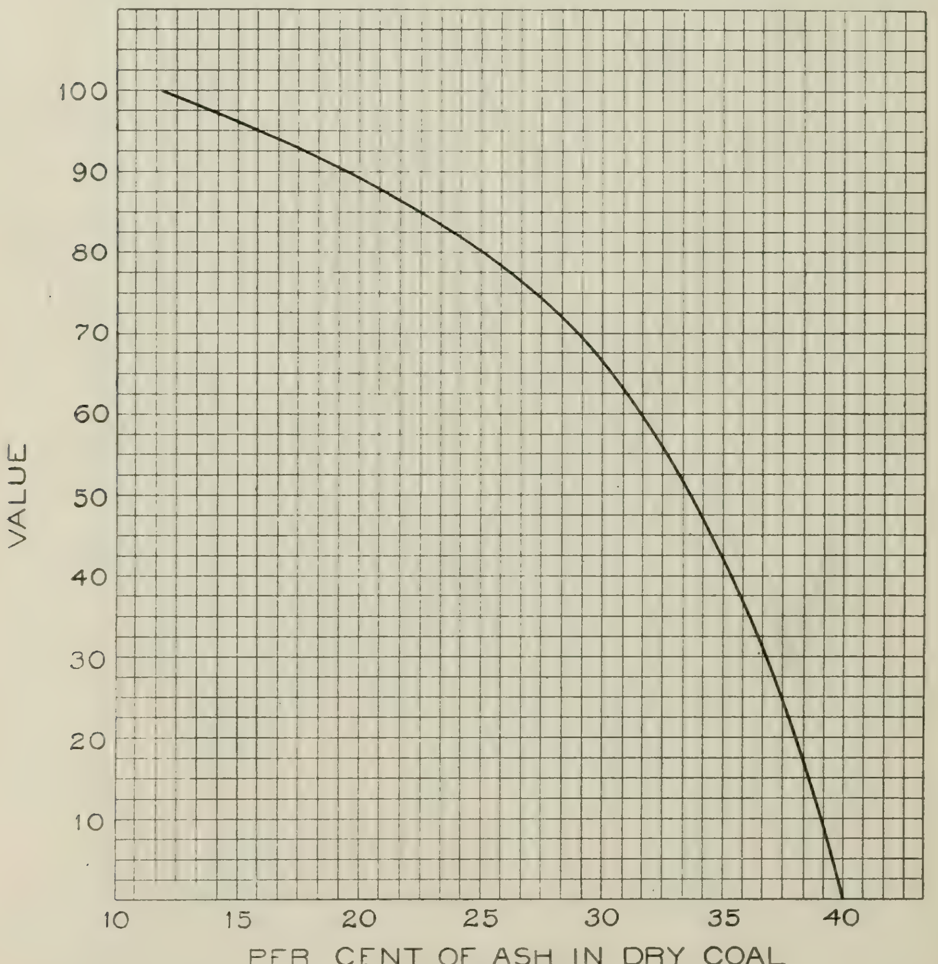



Fig. 8.

concerned, which appears to be 100 per cent., with 12 per cent. of ash in the dry screenings, and according to this, value could be greater than 100 per cent., but 12 per cent. represents an average minimum ash content for coal screenings in Illinois and Indiana at the present time, therefore such fuel is the best obtainable, and for this reason may have a value of 100 per cent. assigned to it.

Thus Fig. 8 contains a curve showing value taken from Fig. 7, and without the complication of curves and points in the latter, and

ash values were taken directly from it for use in the compilation of table B.

The feature of size is a more difficult problem than that of ash, as the following will show. After the tests represented in diagrams Figs. 4 and 5 (62 in number) were finished, Fig. 9 was plotted, using percentages of coal through a 0.25 in. square screen. The diagram for efficiency only is shown, because that for capacity gave no different result. It is apparent that the arrangement of points fails to show any harmful effect due to presence of excessive quantity of fine dust. The fuel used in these 62 tests was ordinary screenings, containing varying amounts of ash, and to ascertain if this variable ash content could be the cause of the failure of Fig. 9 to show harmful effect of fine dust, individual tests were used in the plotting of Fig. 10, the ash content for the tests shown by any one of the curves being constant, while the size as represented by the percentage through the 0.25 in. square screen varied. The result of this analysis made it appear that the presence

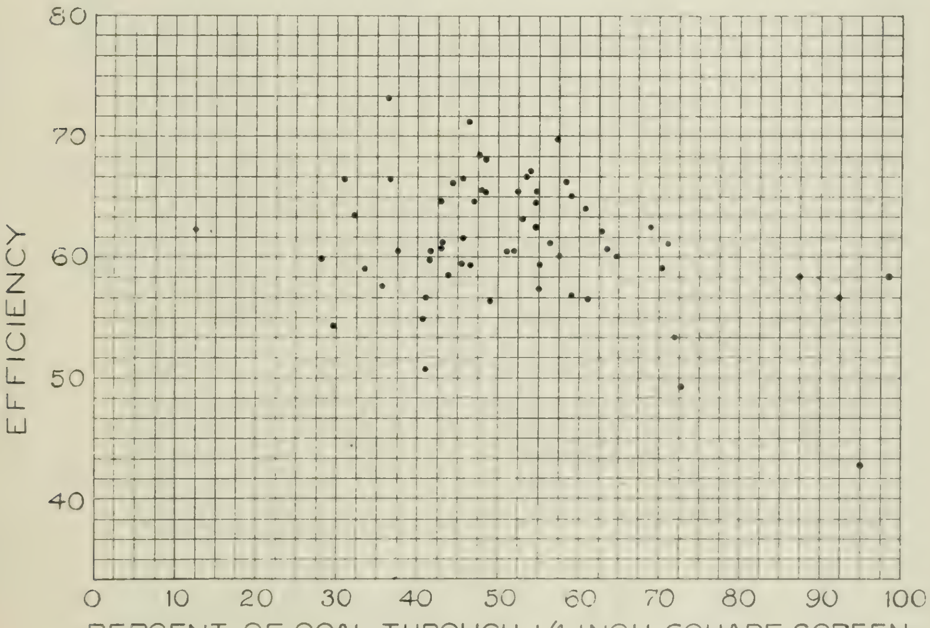



**Fig. 9.**

of finer sizes was sometimes harmful, and in other cases beneficial. The scheme of average size was then adopted and employed, with the result shown by diagrams Figs. 4 and 5, described in the first division of this paper, and as a check on the conclusions of these two diagrams, Fig. 11 was plotted, based on percentages through a 0.5 in. screen. With 1.25 in. screenings, this size is nearer to the general average than that of 0.25 in., and it is apparent that a curve may be drawn through the points which will show a falling off in efficiency or capacity with increase in quantity of fuel through the 0.5 in. screen which helps to corroborate the conclusions of Figs. 4 and 5.

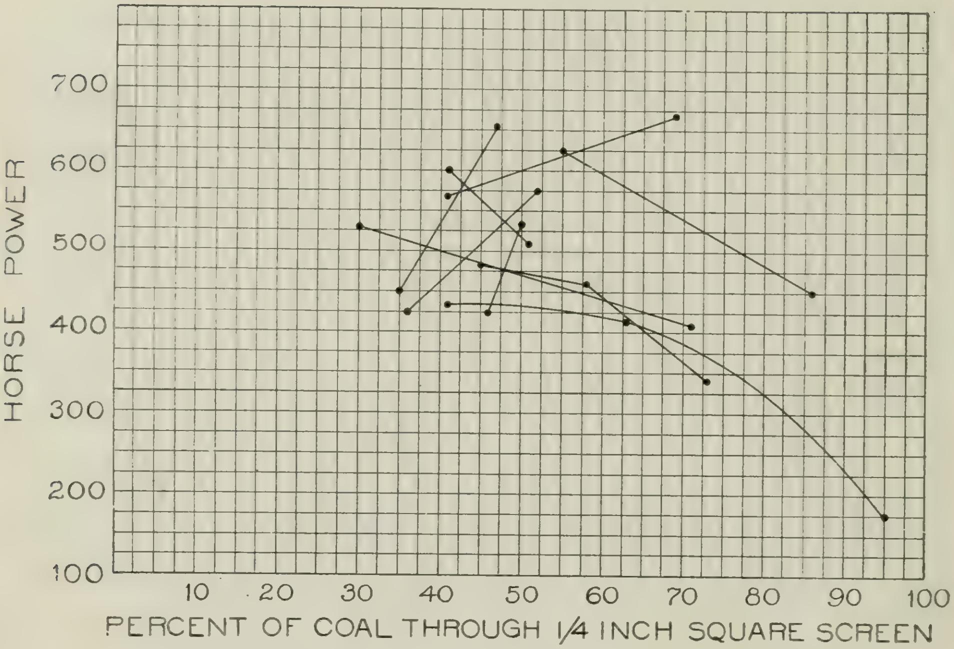



Fig. 10.

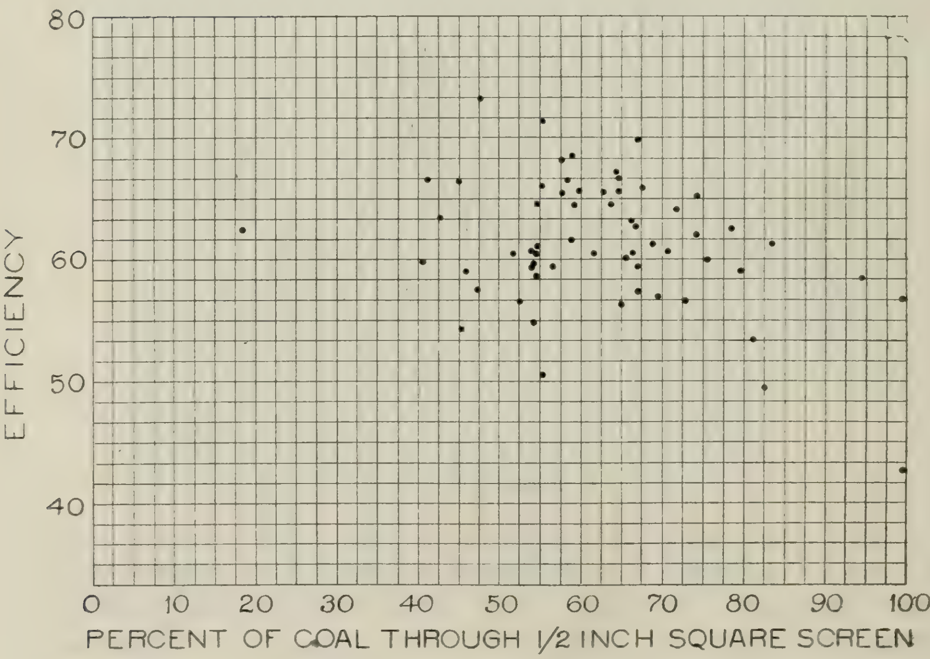



Fig. 11.

In coal inspection service, it is quite essential that the tests be simple and few in number, but determination of the average size requires that several screens be employed, involving a large amount of work, as well as difficult calculation, and for this reason there is

great advantage in using but one screen. The 0.25 in. size having received more or less favorable consideration, in working out a scheme for its use in connection with table B., all of the tests which showed a capacity below 575 horse-power were taken. With these data Fig. 12 was prepared. The average ash in the dry coal for these tests was 18 per cent. A curve representing values for this ash content, and also for standard ash of 12 per cent. being drawn, the latter curve gave values for use in table B. The quantities of coal were transposed from that through the 0.25 in. square to a 0.25 in. round screen. Thus the final result for ash shown by diagram Fig. 8 and that for size by diagram Fig. 12, furnished data used for calculating the final combined values in table B., from which it appears that screenings, having 12 per cent. of ash or less, and of a size that no more than 31 per cent. will pass a 0.25 in. round screen may be considered of 100 per cent. value, or in other words, sufficiently good for the purpose.

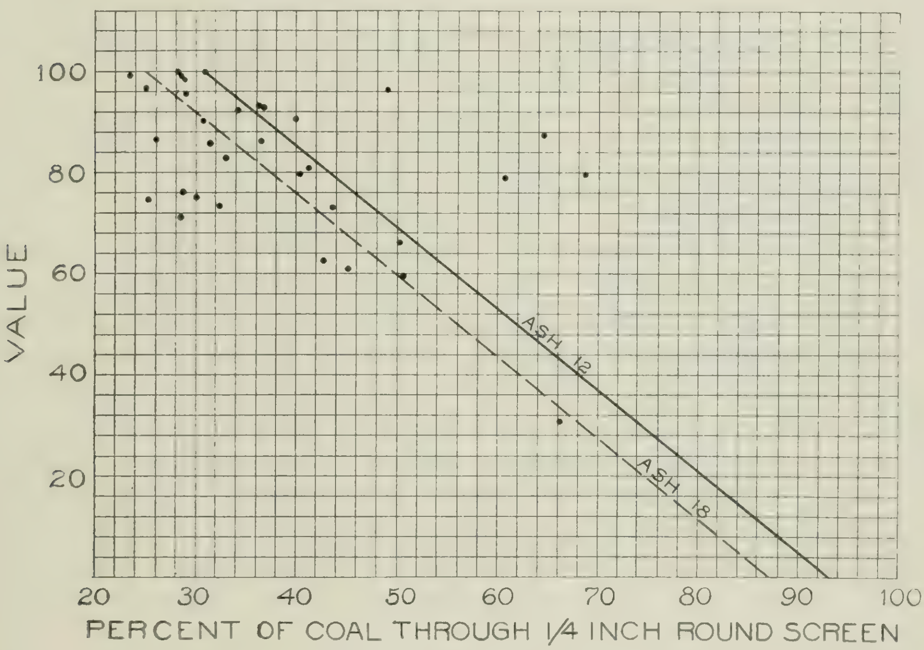



Fig. 12.

Basing conclusions on the measurement given by any one screen is arbitrary, as four points in diagram Fig. 12 indicates, therefore, while table B. may be depended on to identify all of the coal containing an excess amount of fine sizes, it will, in a few cases, condemn satisfactory fuel.

This paper does not presume to lay down the ultimate laws by which fine coals may be graded in value, but rather to point out the fact that such laws, although at present obscure, do exist, and that our conclusions drawn from numerous tests are as herein indicated

During the year 1905 there was produced in Illinois and Indiana

about 50,000,000 tons of coal, 40 per cent. of which was 1¼ in. screenings, and although it was not in every case separated from the lump, we can truthfully say that this 48 per cent., or 20,000,000 tons of screenings, was sold at the mine at an average price not to exceed two-thirds of its cost of production, and this same fine coal was used for making steam at an average efficiency of less than 50 per cent.

These two facts are sufficient warrant for further investigation of this little known subject.

DISCUSSION.

*President Arnold*—Mr. Abbott has brought out some very interesting points, and some of the facts were quite surprising to me. I hope we may have a full discussion by many of those present.

*Walter T. Ray*—(JUN. M. W. S. E.)—I believe this paper of Mr. Abbott's, together with a number of papers presented by Mr. Bement, Mr. Abbott and others previously, marks the beginning of an epoch in the investigation of this subject. I have nothing but commendation to offer for anything Mr. Abbott has said, and any points I mention in the discussion are merely minor criticisms.

I wish to say that the few pages which I am about to read were prepared mainly by Mr. H. Kreisinger and Mr. Harry W. Weeks of the U. S. Geological Survey "Coal Testing Plant" at St. Louis.

It is impossible to prepare artificially coal high in ash, which would behave similar on any grate to coal high in ash in its natural state. When washed coal is mixed with ash, a mixture is obtained which is not homogenous. In such a mixture pieces of nearly pure coal lie by the side of pieces of ash. These pieces of ash insulate the individual pieces of coal and make ignition very difficult. This is especially true with a chain grate stoker, where ignition proceeds in a vertical plane towards the front of the furnace. If we imagine the coal to consist of small cubes we can see how in such a case only one side of the cube is exposed to the fire. Now if this side of the cube is protected by a piece of ash, the ignition can happen only in a round about way and will be very slow. If the ignition is slow, the rate of combustion is slow and this combined with the air spaces left between the piece of ash will make the weight of gas per pound of combustible very high and consequently the temperature of the furnace very low.

In the natural state of high ash coal, the ash is distributed mostly in thin layers throughout the coal. Even these thin layers contain some combustible, so that the combustible of one piece of coal comes in contact with the combustible of another piece of coal and ignition is easier and much quicker, and hence the results obtained with natural coal may differ greatly from those of the prepared coal.

Better results could be obtained in a hand-fired furnace, with prepared coal as used in these experiments, than on chain grate

stoker. In a hand-fired furnace the new charge of fuel is spread in layers over the already burning fuel. In this case not only the bottom side of the little cube of coal is in touch with the burning coal below, but also the four lateral sides are exposed to the escaping gases. The conditions for ignition are therefore much better with the hand firing than with the chain grate stoker.

The upper half of the efficiency curve in Fig. 3 might well be drawn more horizontal, showing that the efficiency was not much effected until a point of about 34% of ash was reached, and then it dropped very rapidly. With a hand fired furnace and higher draft the drop in efficiency would probably not be so rapid, and the zero point would be farther beyond the 40% point.

### Effect of Size of Coal Screenings On Efficiency

In connection with Fig. 5 it would be interesting to have the weight of air used per pound of combustible, plotted on the same basis as the efficiency. The drop of 7% in efficiency would have to show a considerable increase in the weight of air per pound of combustible. Generally the loss due to excess of air is considered much larger than it really is. The per cent. of $CO_2$ over quite a range seldom shows much relation to efficiency. In about 400 boiler tests made by the U. S. Geological Survey, the only item which had any decisive relation to the loss up stack was the unaccounted for item in the heat balance. Generally, when the loss up the stack was high, the unaccounted for was low, and when the loss up the stack was low, the unaccounted for was high, while the efficiency varied but little. Great loss may result from incomplete combustion, due either to improper distribution of air which is probably the case in these experiments, or due to too little air and the high resulting temperatures. It may be said here that high temperatures (perhaps above 2300 or 2400° F.) delay the combustion of the volatile matter of coal. This fact which in the past has been overlooked in the steam boiler practice, follows from the Van't Hoffs principal of mobile equilibrium, which states:

"If a reaction absorbs heat it is accelerated by the rise of temperature; if a reaction evolves heat it is retrograded by the rise of the temperature; if the reaction neither absorbs nor evolves heat it is neither accelerated nor retrograded by the rise of temperature."

The burning of coal evolves heat and is therefore retrograded by high temperatures.

### Thickness of Fire and its Effect on Efficiency.

We agree that it is generally true that good results can be obtained with either a thick or a thin fire, if the fire is properly taken care of. However the thin fire requires more attention, and on that account a thick fire is more often favored. A thick fire increases the resistance of the fuel bed and therefore higher draft must be carried to get the same capacity.

## The Effect of B. t. u. in Coal, on Efficiency.

We have found it true, as the author of the paper says, that the B. t. u. of coal has very little to do with the efficiency of the steam generating outfit, or the capacity attained; however many engineers do not realize this truth and try to determine the value of coal for steaming purposes by running a calorimeter test. Calorimetric determination is an unreliable indication of the steaming value of a coal in very many instances.

## Efficiency.

Mr. Abbott does not give his interpretation of the word "efficiency" but we assume it is the heat absorbed by the boiler and superheater divided by the heat in the combustible "gasified." This gives a chance to state the ideas held by the Boiler Division of the United States Geological Survey Fuel Testing Plant as to what is the *"true efficiency"* of a steam boiler. As Mr. Abbott says, a perfect boiler would cool the gases to atmospheric temperature, but would include the feed-water heater also, which is not common practice. It is really not fair to blame a boiler for not absorbing that portion of the heat contained in the gasses below steam or water temperature. Therefore the efficiency of a boiler ought to be reckoned on the heat available to it in any case, usually that above its saturated steam temperature.

So far as we know the first attempt to deduce the equation for the *true efficiency* of a boiler, neglecting effects due to absorption of heat of radiation from the fuel bed and hot brickwork, was made by Mr. John Perry, and is given in his excellent book, "The Steam Engine and Gas and Oil Engines," and cleared of mathematics his conclusion is this:

"Any given boiler, working at a constant steam pressure, will always absorb the same percentage of the heat contained in the gases above its water temperature, independently of the capacity or rate of working."

Of course a change in the plan of gas baffling would make another boiler of it.

An elaborate series of calculations of about 400 of our tests was made in test of this theory, with the result that nothing seems to contradict it; our conclusion is that the true efficiency of each of the two boilers we have, is constant at 82.5%. That is, they always absorb 82.5% of the heat contained in the entering gases above water temperature. Of course soot and scale will decrease it a little, but it is remarkably constant. A diagram herewith, Chart No. 1, shows how most of the tests fall close to this value of 82.5%, with fewer and fewer falling farther and farther on each side. For comparison a similar curve is drawn for the same tests using the efficiency ordinarily meant, that is as used by Mr. Abbott, which is presumably item 72* of the code of the A. S. M. E. It will be

noticed how the sides are not symmetrical, and how much wider the hump is horizontally.

In this connection we may speak of the four factors which influence the heat absorbed through any portion of the boiler tubes.

(1) Temperature difference between gases and water.
(2) Density of gases, or number of molecules per unit of volume.
(3) Specific heat of gases at constant pressure.
(4) Velocity of gases parallel with tube surface.

As a rule only the first of these four factors is considered—temperature difference between gases and water. But it requires only a little consideration to see that as the temperature of the gases is raised the number of molecules beating against any square centimeter of surface is decreased nearly as fast, and thus we largely beat our own game.

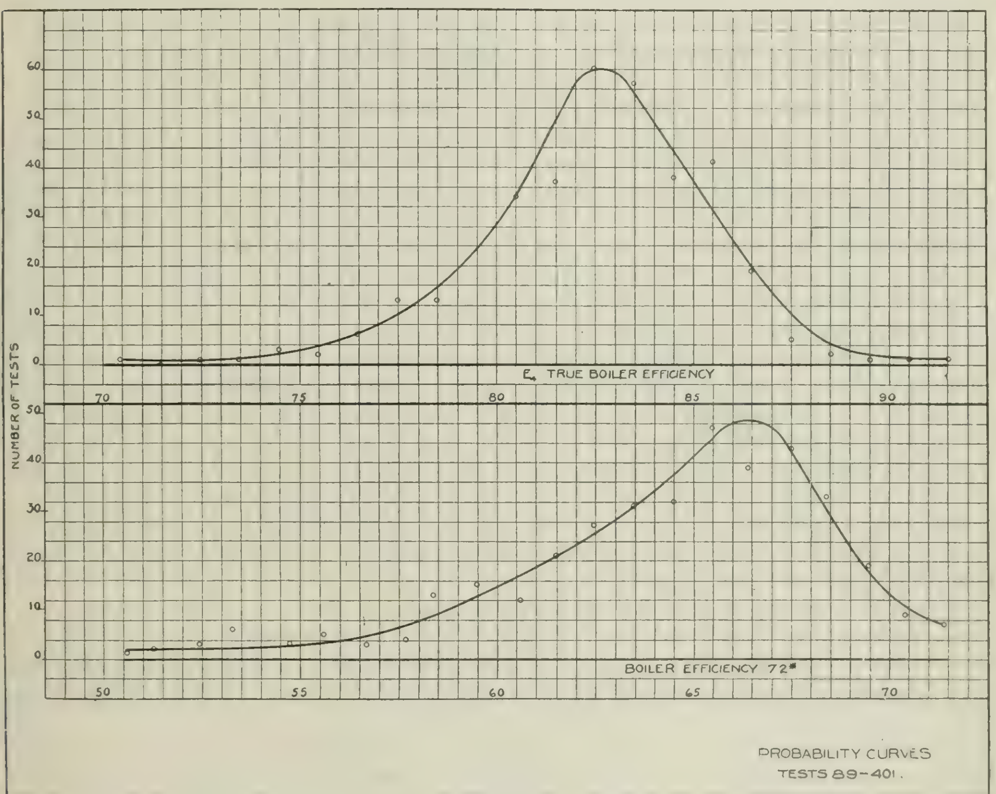



CHART No. 1.

The specific heat of gases of combustion with various amounts of excess air is very nearly constant, so that the third item may be neglected. The fourth item—the velocity of the gases parallel with the tube surface, is what keeps the true efficiency of the boiler as a heat absorber constant throughout all rates of working. The more gas we put through a boiler the more it sweeps the tubes of soot and adhering molecules of cold gas.

Another diagram, Chart 2, shows the product of the four above discussed factors when one pound of carbon is burned with various

amounts of air; it will be seen that after the temperature gets above about 2000° F. very little is to be gained by reducing air supply, so far as concerns heat absorption by the boiler; and at the same time as much may be lost by incomplete combustion due to having less oxygen present. This is another way of stating Mr. Abbott's finding, that under some circumstances about all a "skillful" and "intelligent" fireman can do is to determine how much steam he will make per hour.

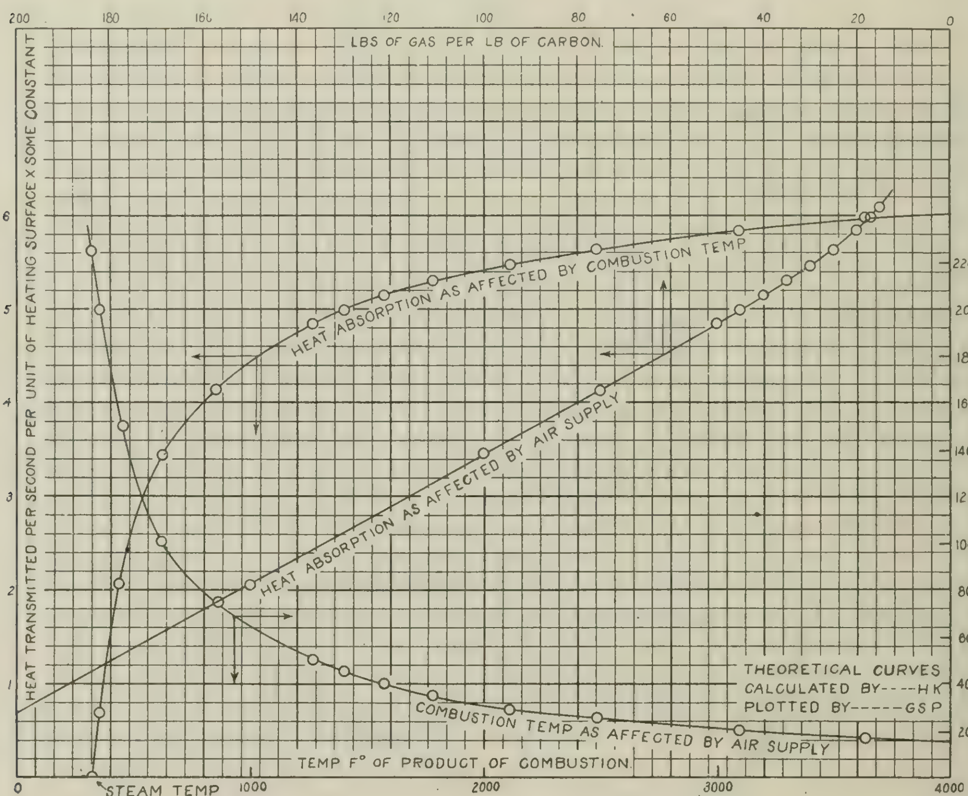



CHART No. 2.

In the diagram, Chart No. 3, the curve No. 4 illustrates the fact that the incomplete combustion increases very rapidly, after the temperature passes a certain point. This chart is of gas analysis, plotted on the basis of the temperature in the combustion chamber. All the points in the chart are obtained by actual observation.

*Prof. L. P. Breckenridge*: (M. W. S. E.)—I have read the paper of Mr. Abbott with considerable interest, and for fear I might talk too long about too many things I have made a note of four things I would like to speak about:

First, we have here a set of extensive experiments to solve an important detail of coal burning. As regards the extent of these experiments you will notice that there are from 85 to 100 tests, evidently 85 boiler trials. Any company that undertakes, in connection with its regular work, to make 85 boiler trials, undertakes a good deal for its own information as well as for the

general cause of science and the helpfulness of others. I think the Western Society of Engineers is fortunate in having presented to it, this extensive set of experiments made under a standard boiler, 500 H. P., equipped with chain grate stokers, a kind that burns Illinois coal exceedingly well.

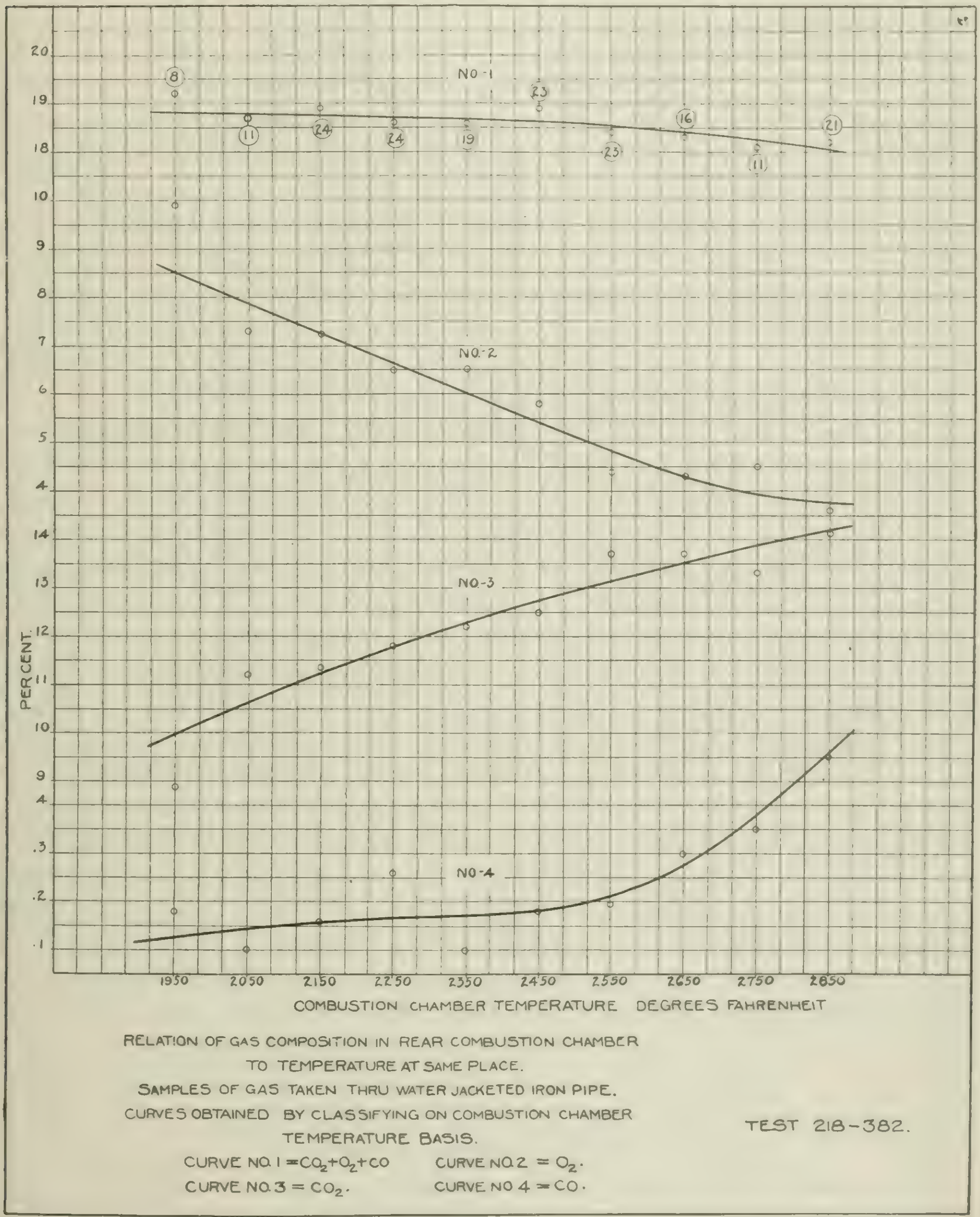



CHART NO. 3.

Second, I want to compliment the author on the fact that he has resisted the temptation of elaborate details in the paper. I have no doubt that with the information at hand Mr. Abbott could have gotten out a paper of 50 to 100 pages easily, but I think that for presentation to us here tonight this is about right. We can manage to get through it. I have no doubt that some people will feel in-

clined to ask a series of questions, from one to a hundred, why he did not give this and that. I have noted one or two things I would like to know about, but they will doubtless come out in the discussion. Third, the fact that the work has been done by people we know, and that they have drawn a conclusion for us that is just what we like to see. These conclusions will be valuable to us. Table B and Figures 8 and 12 answer a question, which has often been asked, in a seemingly satisfactory manner. The question answered is, "what shall be the basis for determining the value of various coals commercially?" It has been supposed, in years gone by, that the only way to determine the value of coal for steaming purposes was by the calorimeter test, but we have learned not to believe that, as pointed out by Mr. Ray, in connection with the Government tests. It seems to me, the answer to this question, at least fits the conditions of this particular apparatus with which the experiments were made, and undoubtedly must be of considerable benefit to the company which is represented here.

The fourth thing is the importance of the study of furnace performance. Mr. Ray has indicated that as far as the boiler is concerned, it always has the same efficiency, and we have come to thoroughly believe that the boiler itself always gives the same efficiency. The reason that the overall efficiency—the efficiency of the plant—is not always the same, the reason why the curves which represent the relation of efficiency to various factors varies, is because of the varying conditions of furnace performance. It becomes evident that the things we are bound to study, and the things which this paper presents as a study, is the performance of furnaces; that is, how to *burn* coal. There is a great variation in the performance of all furnaces, and it is really that which needs our most careful study. It has seemed to me, in the last year or so, that any coal could be burned with equal efficiency if the conditions were right, and I thoroughly believe that, if we could afford it, we could pick out, say, 25 different grades of Illinois and Indiana coals which were representative coals, and that furnaces could be designed in which those several coals could be burned with equal efficiency. You all realize that such a condition has never yet been obtained. Whether or not we could afford to design as many furnaces as it might take is a problem. I believe it would pay and that the furnaces would not be very different.

The determination of curves such as are shown in this paper makes a very interesting study. As the author states, it is hard to say exactly why he twisted some of these curves into the shape he did. Fig. 9 is a good shot-gun curve; it is not a curve at all, and many people that have experimented and obtained results like this, have said, "this does not represent anything; I do not think I will show it." I think we ought to show up those things; it encourages others to go ahead and do something, and out of all of it we shall get much good. The electrical people are in the

habit of making curves of everything in their line, but very little has ever been done with boiler furnaces that approaches this practice. I think the time is coming when, with improved appliances, and more exact knowledge we shall be able to do some things a great deal better in connection with the methods of burning coal than we have ever yet done. We now have better appliances for studying performances and we have improved boiler settings and furnaces, and people who are expert in handling them.

The Fuel Testing work of the U. S. Geological Survey at St. Louis has already begun the design of a special long combustion-chamber furnace, in which to study the problems of burning coal, and this work should prove of much value to the users of Illinois coals.

*W. A. Shaw* (M. W. S. E.)—I have listened to Mr. Abbott's paper and the discussion with much interest. As far as Chicago is concerned, we have not as yet had much experience along the lines of the particular kind of equipment taken into consideration in this paper; that is, water tube boilers and chain grate stokers. The City has in the Water Department eight large pumping stations which consume approximately 60 to 70 tons of coal in 24 hours. In most of the stations the equipment is Scotch marine boilers with Hawley Down-Draft furnaces, hand-fired. The City has, however, recently installed at one station, and put in operation about three weeks ago, a plant equipped with water tube boilers and chain grate stokers. At another station there also is being installed water tube boilers and chain grate stokers. Later we hope to be able to make comparisons as to the different kinds of coal that may be best suited to the chain grate stokers and also for the Hawley down-draft furnaces.

Prior to the first of January, 1906, the City bought coal on the evaporation basis; that is, the contractor was required to guarantee how many pounds of water could be evaporated by a pound of coal in the various pumping stations. When bids were received the results would generally be that the contractor would guarantee that he would evaporate the same number of pounds of water in all of the stations, regardless of what the equipment might be in a particular station.

About the first of January there was originated in the Water Department what is known as the Inspecting & Testing Division and when the specifications were prepared for coal for 1906, both the calorimeter test and evaporation test were taken up. That is, the contractor was asked to state how many pounds of water he would evaporate per pound of coal in each of the pumping stations, and also give the B. t. u. value, percentage of ash, percentage of moisture, etc.

In connection with this I wish to state that the City is not situated as a private consumer. Mr. Abbott began making various tests on various sizes and kinds of coal from various mines. and

determining from which mine it was most advantageous for him to buy. The City must advertise for its coal, and naturally the contract must be given to the lowest responsible bidder that will guarantee the best results for the money paid.

After originating the Division of Test, Mr. P. C. McArdle, M. W. S. E., was put in charge, and the evaporative and efficiency tests were taken away from the Chief Engineer of the stations and conducted by Mr. McArdle with his own assistants. Following this we obtained different results in different pumping stations. At present we take calorimeter tests in connection with evaporation tests, and we use that in computing our boiler efficiency. Today we find, especially on the Hawley down-draft furnaces, an element of interest in the personnel of the boiler room. For example, take the four pumping stations, "Chicago Avenue," "Springfield Avenue," "Central Park," and "14th Street;" each of these stations are equipped with Scotch marine boilers and Hawley down-draft furnaces; by the calorimeter test we determine the heat value and know whether this particular engineer is burning coal to better advantage than others, and it is a check on the others. In some stations it was noticeable to us that before these tests were started there was quite a difference in the duty placed on 100 pounds of coal. After starting the tests we found there was quite a marked difference in the heat efficiency. After running two or three of these each engineer was notified or told what his efficiency should be, and the result has been quite a marked increase in efficiency and much better results have been obtained. I have a plat showing weekly the duty performance at each station with 100 pounds of coal, and while it may not be of great value, still it shows a general increased efficiency. We find by this, as I said, that the personnel in the boiler room, especially for hand-fired furnaces, is quite an element, which I presume would not enter so much in mechanical stokers with chain grates.

We have made some experiments in connection with Hawley down-draft furnaces between lump coal, mine run, and also in burning fine coal, nut coal and screenings, but the results were not satisfactory. We find on Hawley furnaces, that possibly we can get the best efficiency out of lump coal, but the increased price that we have to pay between lump and mine run coal will not warrant our using the lump coal. We have determined, on the tests so far made, that as far as the cost of evaporation of 1,000 pounds of water is concerned, we can evaporate cheaper from mine run coal on Hawley furnaces than we can with lump coal. The element of draft in connection with the Hawley furnace we find to be a considerable factor, and also the amount of air admitted to the lower grates. We are making some experiments now on the effect of draft on the different kinds of coal with different apparatus, but the experiments are not far enough advanced to have enabled us to reach any conclusions.

*Mr. Robert H. Kuss*—Several points of Mr. Abbott's paper have impressed me as did others raised in the ensuing discussion. Only one matter will I speak of now that comes up in the original paper and that is the statement under "Result of different thicknesses of fire" where it is said that for the particular apparatus employed, it pays to make as much smoke as possible. That remark is startling, even when restricted to the apparatus employed. Not having the complete data at hand upon which the statement is founded, we are forced to accept it as having been arrived at for good reasons aside from the two preliminary remarks of the paragraph which should of course, receive equal weight. Figure 6 would lead us to a conclusion to the contrary, in that it is there clearly shown that the thicker the fuel bed the less the resulting horsepower attained, though at no expense of efficiency. Based on efficiency alone there is no choice as to thickness of fire but when the greatest usefulness of the apparatus, that is, horsepower developed, is aimed at, it pays to have a thin fuel bed or in other words, to make as little smoke as possible, if the amount of smoke varies directly as the fuel bed thickness increases. Judged from the standpoint of smoke eradication, the apparatus employed is not a success and entirely unsuited for a process in which complete combustion of fuel is the object.

Prof. Breckinridge stated that it might be well to design a furnace for each of the different kinds of coal. Since the heat absorber, or boiler proper, extracts approximately the same percentage from the heat delivered to it, it follows that if it is possible to design one combustion apparatus that will result in complete combustion whatever may be the kind of fuel used, this will meet the requirements of his idea. Without attaching any particular name to such an arrangement I should say that a grate carried in a Dutch oven as a starting point for combustion, followed by a chamber in which the incompletely burned gases are intimately mixed with the oxygen present, by suitable deflection tile and fire-brick impediments, all before allowing the gases to reach the boiler proper, would answer for the long flaming fuels and hence be more than ample for the fuels giving less trouble in attaining complete combustion.

*Mr. Edward A. Taylor*—I have been very much interested in what Mr. Abbott had to say this evening, as we burn a large quantity of coal. We have a large number of plants in operation and I do not believe we have over five alike; we have almost every kind of a plant, in all stages, and we are of course operating these plants with the idea of obtaining the greatest possible efficiency. We have made a good many experiments, and wherever we find the best coal for each of the different plants, we put that in. But in the two years we have been experimenting we have been unable to cover anything like the entire field, or find out the best kind of coal to use.

Mr. Shaw stated that he had found he could not handle screenings satisfactorily. On the contrary we have been burning sceenings quite satisfactorily, and have had no trouble because we have been careful to select coal which will coke, and we have effected a great saving.

We have five large plants with chain-grates and water tube boilers, although not 500 H. P. and we are getting quite good results from them, using the finer sizes of coal. In fact, out of a purchased of three to four hundred thousand tons, we have bought only 40 thousand tons of mine run; the rest is screenings or fine sizes of washed coal, such as Nos. 3, 4, 5. We have found in every instance that the fine coal is doing better work than the larger sizes, and of course the great reduction in price has made it very advantageous for us.

I hope to derive a great deal of benefit this year from Mr. Abbott's paper.

*A. Bement,* M. W. S. E.—In reference to Mr. Ray's remarks regarding the result obtained with fuel high in ash on a hand fired grate, he considers, I believe, that a better showing would be secured than with the chain grate; or, in other words, capacity and efficiency would not fall to zero until ash percentages were greater than that in this case, namely, 40%. In this connection it is not possible to present an exact opinion, but I am inclined to the view that the hand fire would not have done any better than this case of the chain grate. With this style of stoker, the ash is discharged as fast as it accumulates, therefore it never rises above normal, but with the hand fire under usual conditions, the ash rapidly accumulates, therefore, in using such fuel as this in question, the ash would be 40% as stated, and this would increase rapidly until the time of cleaning fire, which would make it very clear that, all else being equal, the useful result with the hand fire would immediately drop below zero, unless some other influence was brought into play, and such would be possible with a hand fire. For example, with the chain grate, the operator is unable to manipulate the fire by hand, such as raking, spreading, etc., but with the hand fire he may do so, with the result of closing openings in the fuel bed and breaking caked masses of fuel, therefore if it be assumed that the hand manipulation of the fire shall be beneficial to an extent equal to the harm resulting from the increasing ash accumulation, then the plain grate would be on a par with the chain grate stoker. The above refers to ordinary operating conditions which prevail in regular practice, but, if a shaking grate is used and it is shaken frequently or continuously, it might, and would to some extent, dispose of the accumulating ash, which, no doubt, would give the hand fire an advantage. No one, however, operates shaking grates in this manner, although they should do so. I think the curve as presented, showing value of fuel with different percentages of ash, is sufficiently accurate

to be employed. No doubt later, the matter will be more thoroughly studied. But, in fact, I have used it in the case of a client in Iowa, adjacent to the coal fields of that state, who said that another company in the same city, purchased screenings from Williamson County, Ill., at a much higher cost, and was able to make steam cheaper with them, than from the same class of fuel mined close by, which was something, that, according to former reasoning, would not be expected, because it has been quite generally the opinion that the most economical fuel would come from the nearest coal field. The following table will give the relation in the two cases, in which it appears, that according to the net B. t. u. for one cent value, Iowa would have a considerable advantage.

| | Williamson County | Iowa |
|---|---|---|
| Price per ton | 2.80 | 1.88 |
| Moisture | 10.30 | 14.00 |
| Dry Ash | 15.05 | 25.58 |
| B. t. u. — moist coal | 11,049 | 9,199 |
| Net B. t. u. for one cent | 77,509 | 92,452 |
| Effective net B. t. u. for one cent | 67,898 | 64,716 |

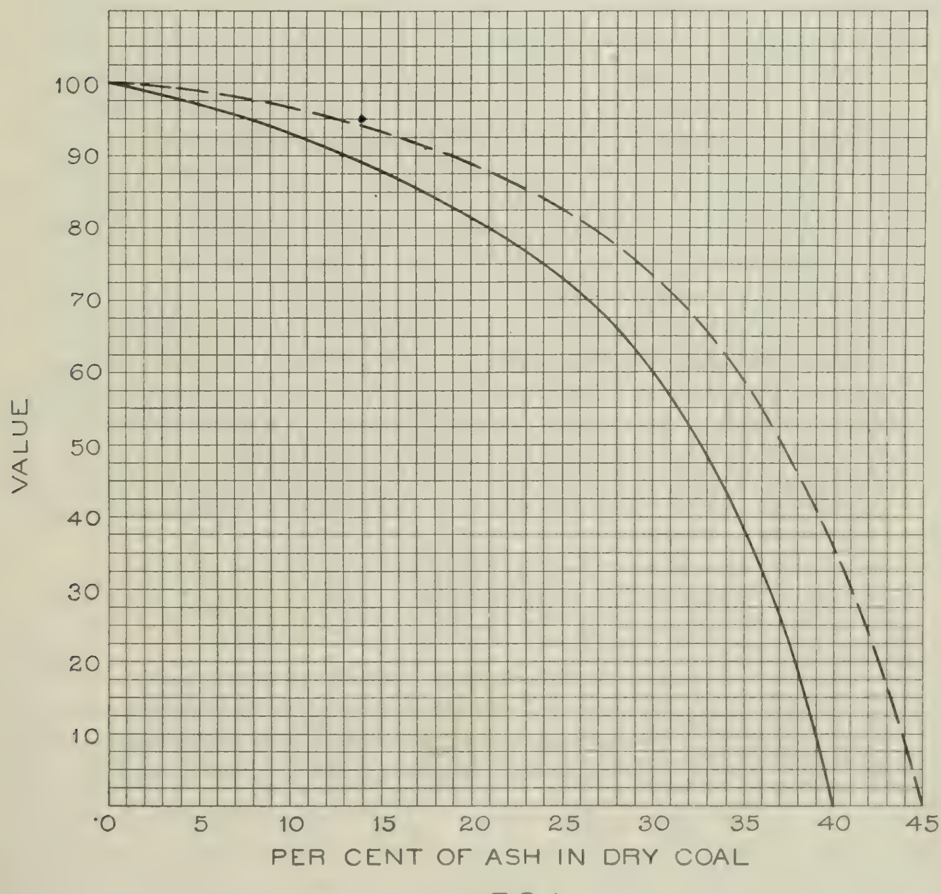



FIG. A

When, however, these two values were reduced in accordance with the effect due to the presence of their respective amounts of ash, the relation becomes changed and the effective net B. t. u. for one cent in Williamson County is 67,898 and the Iowa screenings, 64,716.

The experiments made with different quantities of ash in fuel were with an apparatus not provided with what I term a furnace. It consists in this respect of simply a boiler and chain grate stoker,

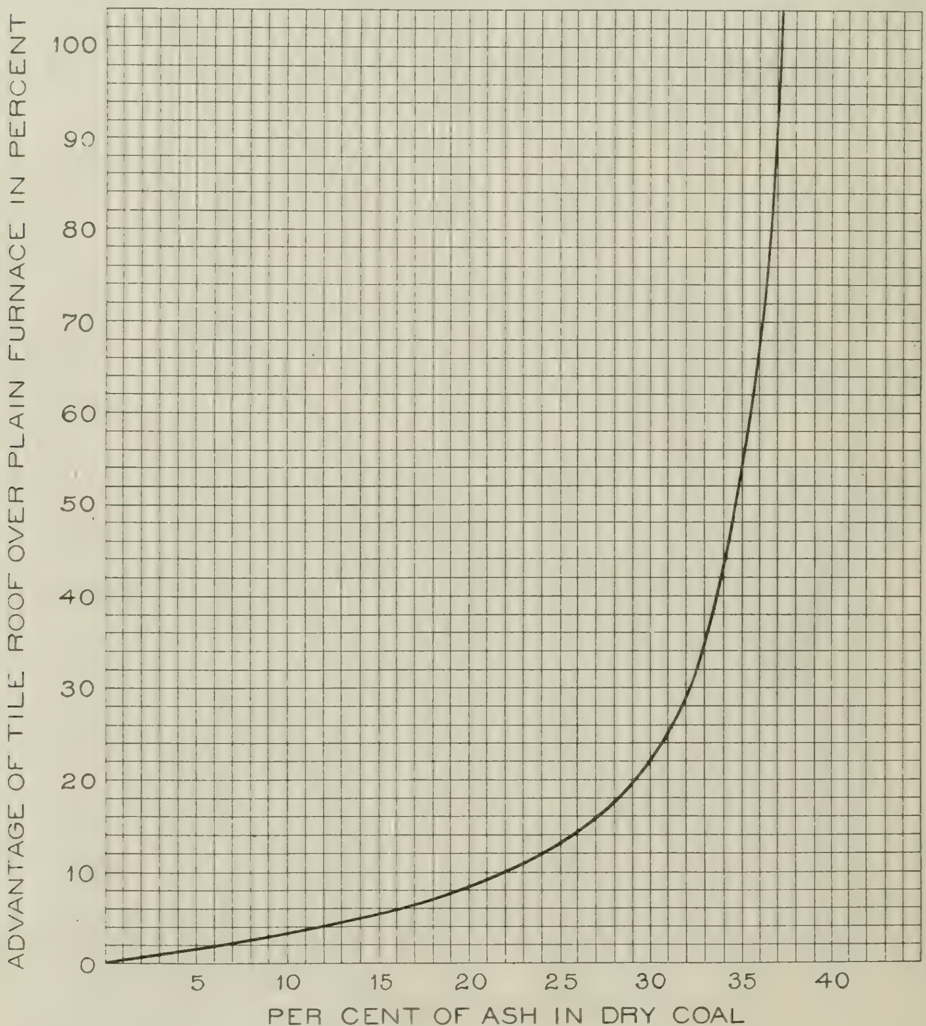



FIG B.

and in this connection I have had an opportunity to test the performance of similar screenings containing 45% of ash in the dry fuel in an apparatus provided with a chain grate stoker, between which and the boiler, a furnace was located, and I found that the efficiency and capacity, instead of dropping to zero with 40% of ash, continued until it had reached 45%, therefore in diagram A, the value of fuel has been recalculated upon the basis of 100% value with zero ash. Two curves are shown, one falling

to zero at 40% and the other at 45%. These two would represent values for the two particular kinds of apparatus. In diagram B a curve is shown which illustrates the advantage of the tile roof furnace over the apparatus without it, with fuel containing variable amounts of ash. This curve is drawn from differences observed in the two curves in Fig. A, from which it appears when a percent of ash has been reached, a little over 37%, that the tile roof apparatus will utilize twice as much heat as the other one, this superiority, of course, falling to zero with zero ash.

Mr. Ray, I believe, calls attention to the fact that in these experiments, the ash added to the fuel was in separate and distinct pieces, and that it was not in any manner incorporated with the fuel, but rather individually separated, and it may be inferred, that owing to this, the result of the tests were correspondingly affected. In this connection, the fact must be borne in mind that coal fuel from this basin seldom or never exceeds 10% of ash in the coal itself, and that the high percentage of ash in screenings as received, is due to the fact that dirt from sources other than the seam itself is mixed with the fuel, just as the ash pit refuse in this test was mixed.

The people of the state have made an appropriation for certain investigations concerning fuel to be made by the Engineering Experiment Station of the State University, and I hope that Prof. Breckenridge will find in the paper presented this evening, some hints which will be useful.

*Mr. F. L. Jefferies*—The paper read this evening carries so many points of interest to me, that I shall probably be thinking of it very forcibly for the next year, and probably all my life, but there is one particular point which impressed me more forcibly than any other; that is, the amount of harm done by fine coal. I think that it was Mr. Abbott's intention to say that a small percentage of fine coal had a very detrimental effect on the burning, or of getting the practical value out of the rest of the coal. In fact it might be advisable to remove the fine dust and not let it enter the furnace at all. This is a subject that I have often considered carefully, but have not been able to answer satisfactorily.

It would be interesting, if some of the members of this Society gave an impression of their experience on this subject, and why it is that the fine coal has this effect. Of course, a number of replies come to mind as to why it is, but the question is, whether those replies are right, and do they embrace all of the real reasons. We are gradually getting to a point where fine coal must be considered, and where fine coal must be handled; but why is it that we cannot get better results from the very fine coal? This is a question I have had in mind for a considerable time, and is one of interest to all of us.

*P. C. McArdle,* M. W. S. E.—The Society I think ought to be very grateful to Mr. Abbott for these extensive tests. In the work

I have to do, Mr. Shaw has practically covered the ground, except a few details in reference to the burning of coal. The coals on which the tests were made by Mr. Abbott are essentially all fine coals. Our tests are made on practically mine run coal. Mr. Shaw stated that our equipments are with Hawley down-draft furnaces, and that our experience with this equipment is that we cannot keep steam pressure up without using large sized coals,—either a good grade of mine run or lump coal, such coal as we get under contract for the City of Chicago.

I wish to make one statement in reference to accumulation of ash in hand-fired Hawley furnaces, as compared with the chain grate stoker recently installed at the "Harrison Street Pumping Station."

With the chain grate the evaporation per hour per pound of coal fired was—

| | Pounds. | | Pounds. |
|---|---|---|---|
| First hour | 8.53 | Fifth hour | 6.2 |
| Second hour | 6.4 | Sixth hour | 6.6 |
| Third hour | 6.6 | Seventh hour | 6.2 |
| Fourth hour | 6.2 | Eighth hour | 6.4 |

The Hawley furnace at "14th Street Pumping Station," also recently installed, boilers and furnace being new, gave the following results:

| | Pounds. | | Pounds. |
|---|---|---|---|
| First hour | 8.4 | Fifth hour | 5.7 |
| Second hour | 7.4 | Sixth hour | 7.4 |
| Third hour | 6.2 | Seventh hour | 6 |
| Fourth hour | 5.6 | Eighth hour | 7.44 |

We note there a fall in the evaporation from the first to the fourth hour; at the end of the fourth hour, the ash had accumulated in the furnace and on the water tubes to such an extent that the evaporation decreased almost one-half, but as soon as the fires were cleaned the evaporation went up again, whereas with the chain grate the evaporation was uniform and normal all the way through.

I wish also to state in reference to the use of fine coal, in the Hawley furnace, that we attempted to use coal, running from 1 in. down to dust, probably 60% passing the half-inch screen. At the "Springfield Avenue Pumping Station" a test was started at 8 o'clock in the morning and we gave it a full trial. We tried to keep the coal on the furnace tubes, but with very poor results. The coal would clinker easily enough, but when the clinker was pulled out the fine coal fell through to the grate and even into the ashpit. The ash determined by laboratory test was shown to be 9%; the ash in the boiler room refuse was 23%, showing 14% of coal going through the grates.

I might also say that we are carrying on each month, in several

of the large stations, evaporation tests, and then making a B. t. u. determination on samples taken from the average of all coals used during these tests. As stated by others, each boiler gives relatively the same efficiency month after month. We are taking up the matter with the intention of trying to improve each of our different plants so as to give the highest possible efficiency for each.

The element of draft is important. In some stations there is a draft of only 0.2 in. while in others the draft is 1. in. I do not say that the efficiency always corresponds with the draft, because it does not, but we find a marked improvement in the running of the different plants by watching carefully what is being done, and testing from time to time the value of coal delivered and the manipulation of the furnace.

At the "Harrison Street Station" I attempted to begin a test at 3 o'clock in the morning. The fireman, in order to clean up the floor, filled in the chute with screenings from the nut coal he was using. He put about two barrows of it into the chute and in about 15 minutes later the chief engineer came to me and said, "please do not go on now with the test because one of the engines has stopped." The fact of the matter was, this fine material contained a large percentage of ash, which clinkered upon the grates, and caught against the fire wall at the back, thus blanketting the fire. The pressure on the boiler fell from 120 lbs. to 80 lbs.—temporarily putting one engine out of service.

*Mr. E. F. Reynolds*—I do not know anything about the combustion of coal, but there is one question I would like to ask, and that is, can anyone tell me why it is that No. 5 unwashed coal contains more ash in proportion, than No. 4 unwashed coal? My idea is that the dust made by the powder shot of the miners in shooting the coal is to a great extent burned. In No. 5 that is washed, the finer particles, the dust coal, is washed out of it, but in the unwashed coal, the burned coal is still there and increases the percentage of ash.

*Mr. W. H. Howe*—About fifteen years ago, when I first started in the coal business, I could have told you gentlemen something about the efficiency of coal, or rather the selling of coal from a salesman's standpoint. In those days one simply offered for sale Lump, Mine Run and Screenings, stating that it was from any one of the coal producing states, and the buyer, in most instances, took the salesman's word as to the quality, evaporation, power, etc.

Today you call on a large concern and the General Manager, Purchasing Agent or their Engineer takes you in hand, fires seven or eight scientific questions at you in rapid succession, and the result is, the ordinary salesman endeavors to back out of the door as quickly and gracefully as he can.

After listening to the discussions tonight, I have decided that the coal man must start all over again and learn the other side.

*Prof. Breckenridge*—In connection with the remark made by

Mr. Bement, suggesting that the Engineering Experiment Station at the State University take up some further details of the subject as discussed here, I will say that I hope we will be able to do something along this line, later on. We are getting ready to make some experiments on coal, and it has been very helpful to have heard this discussion.

*Mr. Bement*—In reference to the dust in screenings, there is no doubt but what it has been on the increase for a considerable time, particularly since the passage of what is known as the "Shot Firers' Bill". I have been surprised in going into mines to learn that the men would shoot the coal as hard as they do, when the amount of labor required in gathering it up is taken into account. In Indiana where a different method of mining prevails, one may see a face shot down in a nice bunch ready to load and not scattered more than about 15 ft., whereas in Illinois, the coal shot down is distributed over a room principally in dust and small pieces for something like 100 ft, and the men must scrape this up and gather it together if they are to secure their tonnage. The result is, that they scrape up a lot of dirt with it, and in this way, ash percentages have been made larger, and the continually increasing ash in screenings is explained.

Boston, Mass., Aug. 23, 1906.

*Mr. Geo. H. Barrus* (by letter)—I am in receipt of a letter from your Secretary, together with a paper by Mr. W. L. Abbott, entitled "Some Characteristics of Coal as Affecting Performance with Steam Boilers," soliciting attendance at the meeting, Sept. 5th, or a discussion of the paper.

I have scanned the paper hastily, and regret to say that it gives so little data regarding the manner in which the tests were conducted, and the conditions attending them, that it is difficult to judge as to the value of the results, and therefore impossible to comment on them intelligently.

*Mr. Albert A. Cary, New York* (by letter)—From information gained, by reading this paper, I am led to infer that all of the different samples of coal experimented with in these tests, were burned under practically one single set of conditions.

This paper, therefore; if I am right, merely shows what can be accomplished with the varying fuels experimented with when using chain grate stokers, with one fixed design and opening in the grate bars;—with the form of furnace construction shown in Fig. 1, and with the described Babcock & Wilcox boiler, having a free draftway between all of its tubes.

There also seem to be limitations in the draft available, which prevented the utilization of fuel carrying 60% or less of combustible matter.

For this particular equipment and for other plants similarly equipped, where changes in furnace and grate design (to meet the requirements of the lower grade fuels) are undesirable; this

information, obtained and collated with so much apparent care, will undoubtedly be of no little value, and if more Central Stations would investigate their fuel conditions as Mr. Abbott has done, very considerable savings in their fuel bills would result.

I am sorry to find that Mr. Abbott has not extended this paper so as to include additional information, which, I believe, would increase its field usefulness materially, such as;—draft pressures, pounds of coal consumed per hour, per square foot of grate surface; gas analysis under the different conditions described, and temperatures obtained in the furnace and flue.

I find that Mr. Abbott has reported his efficiency results in terms of *combined* furnace and boiler efficiency which, I admit, is quite customary and which doubtless gives him all the information he desires for his station operation but, for general furnace performance information, this is somewhat misleading.

At the December 1904 meeting of the American Society of Mechanical Engineers, I gave the following definitions.

*Individual Furnace efficiency,* is the ratio of the total heat delivered from the furnace to the total heat value of the coal consumed.

*Individual Boiler efficiency,* is the ratio of the total heat absorbed by the boiler, to the total heat delivered by the furnace to the boiler.

By multiplying these two separate efficiencies together, we obtain the *combined* furnace and boiler efficiencies.

These definitions were followed with an example taken from a complete boiler test conducted by me, showing one method by which these separated efficiencies were obtained.

At that meeting I called attention to the fact that most steam users seemed to regard the furnace and boiler as one integral piece of apparatus which is *wholly wrong.* They are as separate one from the other as the boiler and the engine.

The furnace, by chemical action, is a *producer* of heat while the boiler (diametrically the opposite) is an *absorber* of a portion of the total heat the furnace delivers to it.

By following the practice, in my work, of individualizing the separate furnace and boiler efficiencies, I have been able to discover with great accuracy every point of unnecessary loss in the operation of boiler equipments, and find a remedy for them. Sometimes the trouble was found in the furnace, sometimes in the boiler, while in other cases, both needed remedying.

Turning now to Mr. Abbott's paper, we see that it refers especially to furnace results obtained under varying fuel conditions and if the furnace lacks efficiency, it does not follow that it is due to faults existing in the boiler, which remains unchanged throughout this entire series of tests.

If the efficiency of the furnace is low, its construction or the method of handling the coal should be altered to suit the fuel used, and when the highest possible efficiency of the furnace was ob-

tained with the coal under test, we would then be able to arrive at the true operating value of this fuel.

Generally speaking, high furnace efficiency is accompanied with high furnace temperatures, and the reverse is equally true with low furnace efficiency.

The difference in temperature between the entering furnace gases and their discharged temperature from the boiler is a function of the boiler's efficiency.

Thus, with no outside disturbing effects, we would find that with a furnace temperature of 1000° above the air and with a flue temperature of 500° above the air, a boiler efficiency of 50% would be obtained and if the initial and final temperatures were 2000° and 500°, a boiler efficiency of 75% would exist, while with 3000° and 500°, we would have a boiler efficiency of 83½%.

High furnace temperatures do not necessarily produce high flue temperatures in boilers, due to the rapidly increasing rate of heat transmission as the difference in temperature between the two sides of the heat transmitting surface increases.

With these statements before us, let us suppose that a low *combined* furnace and boiler efficiency was found during a test. This might have resulted, by some unusual occurrence, from a furnace efficiency of 80% and a boiler efficiency of 50%.

Such a furnace efficiency is good, but I have frequently obtained higher in tests.

Again, our low combined efficiency might have resulted from a furnace efficiency of 66 2-3% and a boiler efficiency of 60% or,—in another case, we might have furnace and boiler efficiencies of 57 1-7% and 70%.

The combined efficiencies in *all of these cases* amounts to 40% notwithstanding, the furnace efficiency varies from 80%; 66 2-3% to 57 1-7%, so we see that the expression of 40% combined efficiency gives us very little idea of what is occurring in the furnace, *per se,* as we are thus measuring its performances, by a more or less efficient boiler.

The highest possible furnace temperatures, within practical limits, should always be striven for to obtain the best fuel economy and it will be found that different grades of fuel require different methods of manipulation to obtain this desired end. Any furnace burning bituminous or semi-bituminous coal having a furnace temperature of less than 1400° Fahr. may be considered as undesirable, as this temperature is required to ignite the most important of all the gases distilled from the coal—I refer to the marsh gas ($C. H_4$), which has a heat value of 23,513 British Thermal Units per pound.

A minimum value of 1800° Fahr. for furnace temperatures is a better figure to adopt.

I do not mean by this, the temperature of the firebed but I

refer to the temperature of the products of combustion discharged from the furnace, or, in other words, entering the boiler.

At the 1904 Summer meeting of the American Society of Machanical Engineers, I called attention to the fact that in carefully conducted boiler tests we have found, that in average practice, for maximum economy, not less than one square foot of effective water wetted boiler heating surface should be provided, for each three (3) pounds of water evaporated from and at 212° (or its equivalent).

This means that an average of 2897.1 B. t. u.'s are supposed to be transmitted to the water per each square foot of heating surface when this rate of evaporation occurs.

With my definition of individual boiler efficiency, given above, we can see that if our boiler (considered apart from the furnace) had an efficiency of 100%; for every 2897 B. t. u.'s delivered per hour from the furnace, ws should provide one square foot of heating surface.

This assumption, of course, does not consider chilling effects from radiation, nor cold air infiltration through boiler settings.

As the individual efficiency of the boiler decreases, we find that a *greater* quantity of heat must be supplied from the furnace to the boiler to properly care for this square foot of heat absorbing surface, as shown in the following table:

| With a boiler *efficiency of* | | B. t. u.'s *required.* |
|---|---|---|
| 90% | For each square foot of heating surface | 3219 |
| 80% | For each square foot of heating surface | 3621 |
| 70% | For each square foot of heating surface | 4139 |
| 60% | For each square foot of heating surface | 4829 |
| 50% | For each square foot of heating surface | 5794 |

With these figures before us let us assume that the draft and grate area in Mr. Abbott's boiler equipment are designed to burn 22 pounds of the coal described, per hour; this fuel, as charged to the furnace, having a calorific value of about 12,200 B. t. u.'s per pound of coal.

Let us further assume a furnace efficiency of 85% and a boiler efficiency of 85% making a combined efficiency of 74¼%.

For each pound of coal burned, the furnace will therefore deliver to the boiler 12,200 x 0.85=10,370 B. t. u.'s.

With 22 pounds of coal consumed per sq. ft. of grate, per hour, this area will deliver to the boiler 228,140 B. t. u.'s.

With a boiler efficiency of 85%, each square foot of heating surface requires 3415 B. t. u.'s and therefore, our square foot of grate will take care of 66.8 sq. ft. of boiler heating surface, evaporating three (3) pounds of water, from and at 212° F. per each square foot of boiler surface.

Let us next consider the inferior grade of coal running high in ash and we may assume this to have a value of 10,000 B. t. u.'s per pound of coal as fired.

Both furnace and boiler efficiency will probably drop,—say 10%, making the combined efficiency $(0.75 \times 0.75) = 56\frac{1}{4}\%$.

By pursuing the same method of calculation as that just given, we find that when burning the same 22 pounds of this coal per square foot of grate, this square foot of grate area will only take care of 42.5 sq. ft. of boiler heating surface and if it is desired to maintain this same rate of combustion, the grate area should be extended about 50%.

Should we desire to maintain the original grate area, we must burn 34.6 pounds of this inferior fuel per square foot of grate to take care of the 66.8 sq. ft. of boiler heating surface, as in the first example.

This rate of combustion with such a grade of coal would tax such a chain grate stoker pretty severely, and would require a forced draft of considerable pressure, applied beneath the grate. It is questionable whether such a stoker could handle 2600 lbs. of coal per hour and properly dispose of between 600 and 700 pounds of refuse (ash, carrying carbon) per hour.

If it was found desirable to use such a coal, (running over 20% in ash) I would design a larger grate, requiring a rate of combustion greater than 22 pounds per square foot but less than 34.6 pounds.

I would burn this coal somewhat less rapidly than the ash would permit without slagging, and use a forced draft under the grate, with a little steam mixed with the air blast. A high rate of combustion is needed to increase the furnace temperature and obtain higher boiler efficiency.

Last, but not least, for such a grade of fuel I would not use a chain grate, although for less abnormal fuels, I believe a chain grate makes a desirable automatic stoker. The chain grate stoker is one depending upon the coking method of firing.

The fresh coal is introduced at the outer end of the grate, where the heat from the firebed beyond and from the fire arch above distills off the volatile matter from the coal, which gas is supposed to run over the hot firebed beyond, and be consumed before entering the boiler. The coke (left after the volatile gases leave the coal) then passes slowly upon the moving grates towards the back of the furnace, and before reaching the rear end of the stoker it is supposed to be entirely consumed, leaving nothing but ash to fall over the discharge end of the chain grate belt.

The higher the percentage of ash in the coal, the further this line of ash extends from the discharge end, towards the front of the stoker and with this advancing ash line, we have less and less of the actual grate surface covered by the combustible matter contained in the coal.

For coals carrying high percentages of ash, my experience has taught me that the sprinkle, or spread method of firing is the best, by which system the coal is constantly spread, evenly and lightly, over the entire top surface of the firebed, thus making all parts of its surface equally efficient combustion area.

As this coal on the top of the fuel bed distills off its volatile matter and then drops below the next fresh charge (burning then as coke) it is gradually consumed and eventually forms a bed of ash upon the grates.

To take care of this rapidly accumulating ash bed, we should use heavy shaking grates, which should be shaken with sufficient frequency to keep the ash pit bright during the greater portion of the time.

To penetrate this dense bed of ash and fuel with air, we should use a forced blast beneath the grate, which blast should be arranged to distribute an even pressure throughout the whole ash pit. Best results have been obtained, under these conditions by using a grate bar perforated with many circular openings and presenting to the ash pit floor as smooth a surface as possible.

The effect produced by these many circular openings with the air passing upward through them, is similar to that obtained by blacksmith forge tuyeres.

This description does not refer to any special or patented system, and the coal may be sprinkled upon the firebed surface by mechanical or hand fired methods.

Where the ash has a tendency to clinker or slag, steam should be used under the grates, and it is a curious fact that superheated steam has proved more effective in disintergrating this clinker than saturated steam.

With bituminous coal, fire arches should be used over the firebed, especially with boilers of the Babcock & Wilcox type, and frequently we will obtain better results with these boilers by using baffle bricks in a portion of the openings between the tubes in the first pass.

The results obtained by Mr. Abbott with small size bituminous coal are quite in accordance with my experience, and his paper shows very clearly the limitations of the chain grate stoker using such fuel.

Had he used a sprinkling system of firing with his coal averaging from ¼ in. to ½ in. in size, with the furnace I have described, his results would unquestionably have been much better than shown in Fig. 2.

Referring to Figs. 3 and 7, we note that with his chain grate stoker the furnace and boiler arrangement, no useful effect is produced with coal carrying 40% of incombustible matter.

This merely shows the limitation of his chain grate stoker, set in the manner he has described, but it by no means proves that

coal with 60% of good combustible matter cannot be burned with useful effect.

I have conducted tests, with a water tube boiler, where the fuel used was obtained from the screenings of a coal pocket. This coal carried 35% of incombustible matter, but I succeeded in obtaining about 60% of the boiler's rating. Mr. W. F. Morse, an expert in garbage and refuse cremation informed me that he has made steam when using refuse carrying as high as 60% incombustible matter, this refuse containing a large percentage of carbon carrying ash collected from private houses.

The effect of size in coal screenings on capacity and efficiency as shown in Figs. 4 and 5 is very interesting, but it must be remembered that this is an effect produced by use of a chain grate stoker, and I questioned whether the same peculiar results (occurring with a coal larger than 3-10 in. would occur in a furnace such as I have described, operated with the sprinkling system of firing.

The explanation given by Mr. Abbott, following Fig. 5 of his paper, *may* be a correct one. I would be better able to express an opinion on this matter if I had an opportunity to make some personal observations, but after giving the matter some thought, perhaps I may be permitted to offer another explanation.

When coal is charged to a fire, a cooling effect follows, first;—due to raising the fuel from the temperature of the fire room to that of the firebed, and second;—due to the heat absorbed by the coal in distilling off its contained volatile gases.

The first effect causes a direct increase in temperature in the coal, and as the coal becomes hotter, it expands and increases in volume.

As the outer surface of a lump of coal becomes heated first, this unequal expansion tends to cause the lump to crack and fall apart and the heat next gradually works its way towards the center of the lump until it is eventually evenly heated throughout.

The larger our lump of coal, the slower this process of heat penetration and the longer the time becomes, necessary to distill off its entire contents of volatile matter.

In furnaces operated with the coking method of firing, where the fuel is moved gradually (during its various phases of combustion) from the position of charging towards its place of ash discharge;—I have found that the position of the line of complete distillation of its gases materially affects the capacity and efficiency of the furnace.

Generally speaking; practically all of the volatile matter contained in the coal should be distilled off before the coal has travelled one third of the length of the grate.

This leaves the balance of the grate (excepting the extreme ash end) free to generate the high temperature necessary to produce both boiler and furnace sufficiency including the temperature necessary to rapidly heat the green coal and distill off its volatile matter.

Of course we know that the fixed carbon burns *directly* upon the grate while nearly all of the volatile matter is consumed in the combustion chamber, over or beyond the grate.

As the heat penetration to the center of large lumps is slower than its penetration to the center of small lumps, the non-coked coal of large lumps will be carried further into the furnace than is the case with small lumps.

The same effect is produced when we feed even small lumps too rapidly into a furnace operated upon the coking method of firing.

In an automatic furnace depending upon the coking method of firing, we must remember that all parts of our firebed are not equally efficient, as we have; first, the cold entering coal followed by an area where the temperature of this coal is being raised; next comes an area where the gases are being distilled off from the coal and then follows an area where the remaining coke is being burned.

This is followed by an area of ash formation and then comes the ash with no heat producing quality.

This form of stoker is most effective when the largest percentage of its area is kept at the maximum firebed temperature.

Notwithstanding all the defects I have noted the stokers depending upon the coking method of firing are more widely used in this country than any other class of automatic stokers, loaning themselves as they do, more readily to automatic firing than the sprinkling or alternate systems of machine stoking.

The sprinkle method of firing, however, when properly handled has an equally efficient firebed distributed over its entire area and with proper draft conditions, will cause the larger lumps of coal (distributed over a wider area) to break down more rapidly than in the coking method and, where the limitations of the coking stoker are reached by size of coal, the sprinkling method offers a practical means for overcoming such troubles.

If I were trying to dodge the trouble caused by large coal used in coke firing, I would of course say;—crush your coal finer.

As Mr. Abbott has stated, the presence of fine dust in excess is a great and important source of trouble; especially if such dust comes from an unwashed coal, carrying much ash.

This dust fills the interstices between the lumps of coal on a firebed, making the penetration of air (required for combustion) very difficult; producing a firebed full of holes as well as uneven areas of unequal temperature.

If a strong draft, under the grate bars be provided, the fine dust is carried over into the rear chamber of the boiler and into the flue, and besides, covers the heating surface with a more or less non-conducting covering.

The only way that coal smaller than between 60 and 80 mesh can be burned to advantage, is by projecting it into a specially designed furnace, where a high temperature is maintained;—and burning this fuel there, while it is suspended in the air. Even then,

it is necessary to have such fuel quite dry in order to obtain satisfactory results.

Concerning the results obtained by different thicknesses of firebed, it must be remembered that furnace construction and method of stoking have much to do with the results obtained under such conditions of changes, and the draft pressure available and its method of application is a very important consideration. In every boiler equipment, furnished with a certain grade of coal, it will be found that a certain thickness of firebed will secure the best results. Because a firebed is thickened, it does not necessarily mean that more coal will be burned per square foot of grate surface.

The thickness of the firebed should be regulated, first;—so as to prevent the passage of too great an excess of air through its body, and second:—so as not to have too great thickness and thus restrict the flow of air, so as to provide an insufficient supply for complete combustion.

During the course of a series of tests, the most advantageous thickness of firebed can be determined by gas analysis and by noting the temperatures of the furnace and flue. Generally speaking, the greater the draft pressure, the thicker the firebed should be and as we increase *both* draft pressure and thickness of bed, the greater the fuel consumption becomes, per square foot of grate surface.

With results shown in Fig. 6, it seems, at first sight, somewhat strange that the combined furnace and boiler efficiency remains the same with a firebed thickness varying from 4 in. to 12 in. while the rate of evaporation changes with the different thicknesses.

To account for these apparently anomolous results, and with the limited information supplied, we would naturally guess that there was less coal burned per square foot of grate under the large boiler with the firebed running from 8 in. to 12 in. in thickness, than was burned there, when the firebed varied from 4 in. to 8 in. in thickness.

This would indicate a limitation with the chain grate stoker, or a limitation in draft pressure, or both.

A careful series of tests with a separate analysis of the individual furnace and boiler efficiencies would alone give us the true reason for these results and such tests might show us that as the boiler efficiency increased, the furnace efficiency decreased in like proportion, thus giving us a uniform combined efficiency.

With a properly designed furnace and boiler, and with a properly adjusted draft pressure, the increased thickness of firebed should give us an increased horse power output—this, of course, within reasonable limits.

Concerning Mr. Abbot's statement, that the greatest economy is obtained from his boiler constructed with 9 tubes high, when operating his furnace so as to produce *much* smoke I am afraid that I must take exception to such practice.

I have not the slightest reason to doubt, with the limitations imposed by the form of settings in use, that this is a perfectly correct statement, but with such conditions existing, I can state without hesitation, that changes can be made in these boilers and settings which will increase their economy and capacity materially.

There are other deductions to be drawn from the results reported in this very interesting series of tests, but I am afraid that I have already made too much of an intrusion upon your time, so I will close here with hopes that others discussing this paper will bring out further points of interest.

CLOSURE.

*Mr. Abbott*—Referring to the criticism by Mr. George H. Barrus, I will say that Mr. Barrus' name is a sufficient guarantee of the wisdom of his criticism, but I also wish to say that if the company by which I am employed had been compelled to make its tests and report them as Mr. Barrus might require, no doubt these tests would never have been made. We were making comparative tests to bring out certain specific facts, and not particularly for the purpose of reporting them for the criticism of such eminent engineers as Mr. Barrus.

I was very much amused at Mr. Howe's remarks on how the coal salesmen are stalled nowadays. Not long ago a young coal salesman came into my office and wanted me to buy some of their screenings, saying that his company had recently opened a screenings mine in Springfield, and were getting out a good grade of screenings, which they would like to have us try.

Referring to Mr. Reynolds' inquiry, why one size of fine coal contains more ash than another, I will say that I do not agree with him in his explanation, which, if I understand it rightly, is that he thinks that the fine dust and other finer sized coal is burned in the explosion of the shot when the coal is mined. This occurs sometimes, and when it does we read about a terrific mine disaster; the dust takes fire and burns in he air; in other words, there is a coal dust explosion. I think the explanation given in the paragraph preceding Fig. 3 is a reasonable one. "The high per cent. of ash in the smaller sizes is not due to ash in the coal itself, but to the fact that all of the fine sized foreign matter separated from larger coal, or which comes from roof or floor of the mine, naturally finds its way into this smaller coal."

Some comment has been made upon the fact that a private consumer should undertake tests to the extent which have been reported here this evening. I think it is unusual. I do not know of any other company that has undertaken it; it is unjust that any company should undertake it. The Government is supporting a Coal Testing Plant in St. Louis, and the state of Illinois one at the State University, and it is in such plants as these that the questions should be worked out rather than have the burden and expense fall upon an individual company.

*Mr. Bement* (by letter)—Recalling the discussion of this paper, it seems well that some of the features have further attention, therefore I submit the following:

Referring to a size of screen which may be employed for unwashed screenings when only one is used; if of small mesh, necessitates drying the coal before it can be tested, and this results in a considerable amount of dust being taken up by the air in the room, which is sometimes an objectionable matter.

Regarding the use of the word *efficiency,* there is a great deal of confusion, one often not knowing to what feature of performance or of the apparatus, reference is made, and frequently the word is used without defining its application. The Engineering News published an extract from this paper and changed the title to read. Some Characteristics of Coal as Affecting Performance "of" Steam Boilers, thinking, no doubt, that the author had not used the right word, yet, variation in fuel could not affect the efficiency of the boiler, because it remained unchanged, therefore the efficiency of this particular boiler, whatever it may be, was necessarily constant and unchanged in all of the tests, and its efficiency could not differ without altering its metallic structure in some manner, and this reasoning, in fact, applies to the entire apparatus. The change in fuel, a variable factor acting in conjunction with the constant influence of the apparatus itself, produced changeable results; or, in other words, a variation in total final efficiency obtained in the different experiments.

In the experiments in this paper, the heat realized in steam divided by the heat in the original fuel, determined the efficiency, and was not based on combustion and heat absorption, as would appear from the discussion offered by Messrs. Kreisinger, Weeks and Ray. The object of these experiments was to determine the influence due to variation in fuel, therefore the measure of efficiency necessarily took into account the object of the tests. Some features of this phase of the matter are to be found in the Transactions of the American Society of Mechanical Engineers, Vol. 26, pages 418 and 619. It is these to which Mr. Cary refers. The discussion offered by the U. S. Geological Survey has only an indirect bearing on Mr. Abbott's paper, and is of such character as to demand that it be again presented in the form of an original paper.

Regarding the percentage of $Co_2$ seldom showing much relation to total final efficiency,—this is true in many cases, and the reason for it is due to imperfection of apparatus or difficulty in manipulation. For example, the apparatus used in the experiments mentioned in this paper, did not insure complete combustion, therefore a decreasing excess of air was necessarily accompanied by a larger escape of unburned volatile gases, so as shown in Fig. 6, the losses balanced, causing a uniform result as far as efficient utilization of the heat was concerned. In this case the trouble was not due to manipulation but to the fault of the apparatus, because if there

had been a furnace of sufficient capacity located between the boiler and stoker, the volatile gases would have been burned and there would have been a relation obtained between $CO_2$ and total final efficiency. In the case of boilers in the Geological Survey plant at St. Louis, the firing is by hand, and for this reason it is impracticable to secure that uniformity in feed of coal insured with the chain grate stoker, therefore as $CO_2$ increases, due, of course, to decreasing excess of air, there is a larger escape of unburned volatile matter, but it is true that the per cent. of $CO_2$ and the efficiency, bear a relation to each other unless some intervening influence counteracts the effect due to the decreased air supply. Very often people attempt to improve the economy in steam generation, and are guided by the percentage of $CO_2$, and often find, notwithstanding the fact that they get a decreased air supply, that the efficiency does not rise due to the cause illustrated in this Fig. 6. The remedy, of course, is to secure complete combustion.

I do not consider it advisable to assume that the calorimeter is an unreliable instrument in determining the value of fuel for steaming or other purposes, because it does its work in an accurate manner and accomplishes all that should be expected of it. The trouble is not with the calorimeter or the calorimetric method, but with the people who fail to take into consideration other features of equal or even greater importance.

As I understand the matter, Mr. Abbott did not attempt any discussion relative to the functions of a perfect boiler, but made use of a simple illustration to show why the total final efficiency remained constant as shown in Fig. 6, and the assumption was, that if a boiler would cool the gases to the temperature of the atmosphere, all of the heat generated would be removed, and if this were possible, there would be no limit in excess of air, because all the heat furnished would be absorbed. A boiler to fill such a requirement would have to be of unlimited extent, and, of course, impracticable, but if, in an analogous case, one boiler should be larger than the other, such as Babcock & Wilcox type 14 tubes high instead of one 9 tubes high, then the higher boiler would cool the gases to a greater extent than the lower one, and for this reason, with this particular high boiler, the loss due to escaping volatile matter and excess of air, balanced each other, which is not the case with the one 9 tubes high.

The reference to the ability of a "skillful" or "intelligent" fireman to produce economical results, referred to the particular apparatus in which the experiments were made and not to apparatus under conditions in general, because manipulation has a very important effect on the economical result secured in steam making in all but exceptional cases like the one in question.

I do not think it wise to assume that the rate of work or amount of capacity obtained through a boiler has no effect on the efficient result finally secured. It is certainly very clear that when the

apparatus is driven harder, that the temperature of escaping gases necessarily increases and less percentage of the heat flows into the boiler. This has been discussed and illustrated in the Journal of the Western Society of Engineers, Vol. 6, page 231.

Quoting from the discussion of Mr. Kuss, wherein he says—"Only one matter will I speak of now that comes up in the original paper, and that is the statement, where it is said that for a particular apparatus employed, it pays to make as much smoke as possible." Mr. Kuss' inference is not clear, and it may be he considers that the remarks in the paper refer to the boilers with which the experiments were made. The statement in the paper, however, was, that with the low type of boilers, such as, for example, 9 tubes high, when the gases flowed immediately among the tubes, a gain in total efficiency resulted when conditions were favorable to the production of most smoke, or, in other words, when the fire was thick and the excess of air small.

Referring to Fig. 6, I would have drawn the solid curve representing horsepower, in a somewhat different manner; instead of passing through the two points with a fire thickness of 4 in. and 6 in. I would have made it slope off toward the thinner fire, with the peak at about a 6½ in. fire. There were three sets of tests for each thickness in the series shown by the solid curves. The fuel used for the purpose was washed screenings of a very uniform size for such fuel, but there was a moderate variation in both size and ash content, and in making this diagram, the test for each thickness where there was the least variation in ash and size, were taken for the purpose of this diagram. When all of the points for horsepower were plotted, this capacity curve assumed the characteristic mentioned, with the peak at about 6½ in. It is observed with the smaller coal, represented by the broken lines, that the maximum capacity occurs with a thinner fire, but if the coal had been larger than that employed in the tests shown by the solid curve, maximum capacity would have been secured with a still greater thickness of fire.

Referring to the statement of the young man whose firm had just opened a "screening mine," it is not so much of a joke as it might appear, because, owing to the increasing use of heavy blasts in mining, some of the operators have felt that their mines were gradually becoming more particularly producers of screenings than of lump coal.

Referring to Mr. Barrus' letter, the apparent intimation is, that the tests are not worthy of attention on account of the records not being published. As the author of the paper stated, the object was to ascertain the total final efficiency as influenced by variation in fuel and different operating conditions. The results were fully stated in the paper, and their value could have in no way been increased by the accompaniment of the enormous mass of observations, records, etc. In this connection, it is well to have in mind the

fact that there were more tests in these series of experiments than have so far been published by the boiler test division of the Geological Survey, and if elaborate records had been included, it would have made the publication of the paper very expensive to the Society, but as Mr. Barrus has raised the question, it may be interesting to state how the tests were made.

Each series, except the one illustrated by Fig. 6, were with a uniform thickness of fire. A "running stop and start" was made in every test, or, in other words, the alternate method of the American Society of Mechanical Engineers was used, except that the period was shortened from ten to four hours, but before every test was started, the apparatus ran a sufficient length of time to fully develop the condition. The water measurements were taken by a Keystone meter which had been calibrated. The water line in the gauge glass was brought to the mark each hour and the meter read. Coal in the hopper was at an exact height at the stop and start, and during the test was maintained approximately at this point. All observations and records were made by at least two persons; the essential ones follow:

| | |
|---|---|
| Steam pressure, | Feed water temperature, |
| Water measurements, | Temperature of superheated steam, |
| Coal weights, | Coal analysis. |

These were taken very carefully, and other observations were also made, although the records were not sufficiently complete to make heat balances, one important feature lacking being the loss of combustible in the refuse, the determination of which in such extensive experiments is very expensive.

In calculating the work done in the superheater, the specific heat of superheated steam was taken at 0.75 for the prevailing steam pressure of 180 pounds. The steam temperature was measured by a thermometer. The quantity of steam which passed through the superheater was known from the amount of water fed into the boiler. This made it possible to obtain the heat added to the steam, and each 965.7 B. t. u. added to the steam in the superheater, represented an amount of heat equal to the evaporation of one pound of water from and 212° F., or, in other words, represented one pound equivalent evaporation. On this basis, the work in the superheater was added to that in the boiler, giving a total equivalent evaporation in pounds from and at 212° F. per pound of coal fed by the stoker, and the B. t. u. in this number of pounds of equivalent evaporation obtained per pound of coal fed by the stoker, was divided by the B. t. u. in one pound of the coal, and the result gave what is called in this paper, efficiency.

Some features of the performance of the superheater of the large boiler are given in the Transactions of the American Society of Mechanical Engineers, Vol. 26, page 608.

# THE PROPOSED "INNER CIRCLE" SYSTEM OF CHICAGO SUBWAY TERMINALS.

ARTHUR S. ROBINSON, M. W. S. E.

*Presented September 19, 1906.*

In approaching a subject of the nature and magnitude of the Chicago Subway System, it is essential that it be resolved into its logical elements, and each studied in its entirety, but with reference to the whole.

The particular feature of the problem that interests me most, and the one to which I desire to call attention in this paper, is the down town Terminal Facilities.

The city of Chicago has yet within its possession a vast opportunity for the development of a system of Street Railway Subways that can, and ought to be, the result of the best practice and experience of other cities. It should be one homogenious system, that will meet all the requirements, and afford ample relief at the present time, and yet be elastic enough to make it possible, after the first installation, to meet the needs of increased traffic with a comparatively small expenditure, as the area of the distribution of that traffic increases, as it will do, and as it is continually doing.

It would be a calamity comparable to the "great fire," with probably no such ultimate good results, if by any jugglery of franchises, or by the great clouds of dust raised by designing parties to blind the people to their best interests, the sub-space of the streets should become lost to the free and untrammelled use by the city of Chicago for the street railway subways. This is the only space left for the construction of a comprehensive system of passenger transportation to relieve the congestion that even now has become at times intolerable.

The street surfaces have been so occupied by the tracks of the different, and often antagonistic systems, endeavoring to get their terminals into the busiest possible portion of the down town area, consistent with economy of construction and operation, that it is a huge undertaking to try and bring a uniform system out of the diversified interests now occupying these streets. The result of this construction of individual lines without reference to the tracks or requirements of the other entering companies, and with no well formed plan for a system as a whole, has been that there existed in the streets of Chicago a very large mileage of street railway that was operated at such cross purposes as to fall far short of its own possibilities, if rearranged, simplified, and united in one harmoniously working whole.

The conditions are now better than they used to be, efforts having been put forth by the city authorities to improve them and, with

better results, by the reorganizations of the street railway companies themselves, combining with or obtaining control of tributary lines, and spurred by the increasing volume of traffic.

It is evident that but little relief may be expected from the elevated railway systems, more because of the objection to the occupancy of any new territory in the streets of the down town district, than of any constitutional or structural failure. The opposition to any rearrangement even, of the down town terminal would be almost insurmountable. This has shown itself very unmistakably in the stop put on the extension of the station platforms, when it was hoped that this extension would have increased twofold, the capacity of the loop to handle passengers.

Therefore, the space below the streets presents the only remaining and untouched opportunity, which if properly studied and treated will be the solution of the traffic problem of the city. If imperfect or makeshift systems, or corporations, are allowed to occupy it, to the embarrassment of a full and complete operation of a comprehensive and harmonious solution of the problem, the passenger subways will be forever handicapped or crippled in their fullest development, just as it is now almost impossible to make any improvement in the surface lines.

For this reason it should be the constant desire and effort of all good citizens who have the city's interests at heart, to hasten the time when the city will wake up to the importance of the subject, and appreciate the vast possibilities for a technically easy solution of the transportation problem.

No claim is made that what is here presented is the solution of the problem, but rather that it is a plan that has at least a number of features to recommend it, and which it is hoped may prove to be of so much value that they may be incorporated in the final plans.

It seems emminently proper that this society should take more than a passing interest in the Chicago subways. First, because of the engineering features of the problem, but more because it is a question that appeals individually to a larger number of us, perhaps, than do the majority of the subjects that come before the Society for discussion. It also seems to me that no greater honor could come to it than to draw attention to this matter now, while the field is yet unoccupied, in order that a systematic study of the problem may be made, to the end that tentative plans, at least, may be drawn, so that whatever may be done with conduits, be they large or small, sidewalk areas, river tunnels and other related works, may be done upon the lines of a general plan that will leave the space that must be occupied by the subways, free for their development to the limit of its capacity.

Recently there appeared in the *"Engineering News"* (Dec. 7, 1905), an article explaining and illustrating the proposed terminals of the contemplated Manhattan Bridge. The essential feature of these terminals, the loops, coincides so completely with my idea

of the most effective rapid transit terminals, that it encouraged me to take an added interest in my scheme of the "Inner Circle System" for the terminals of the Chicago Subway, as I have called my plan, and lay it before this Society for discussion.

Where the conditions will permit of its installation, it seems almost superfluous to insist upon the adoption of the loop as the essential feature of any system of terminals where a continuous movement of the traffic must be kept up. And yet there has been a very elaborate treatment of this problem for Chicago, in which it practically has no part.

The ability of any railroad system to handle its traffic, depends more than anything else upon its terminal facilities. This is so self evident, and has been so often illustrated in the vast sums spent by railroads, both inter-state and urban, that it seems almost superfluous to state it here. So it would seem that a terminal system for the Chicago Subways that will permit the handling of the rolling stock and passengers to the fullest capacity of the lines to deliver this traffic to the terminals, is the desideratum to be striven for, and it appears to me that the system finally adopted to accomplish this must be some form of the loop. Since the sub-surface of the streets of Chicago is as yet unoccupied, the opportunities are unlimited for the development of what might be termed an ideal system.

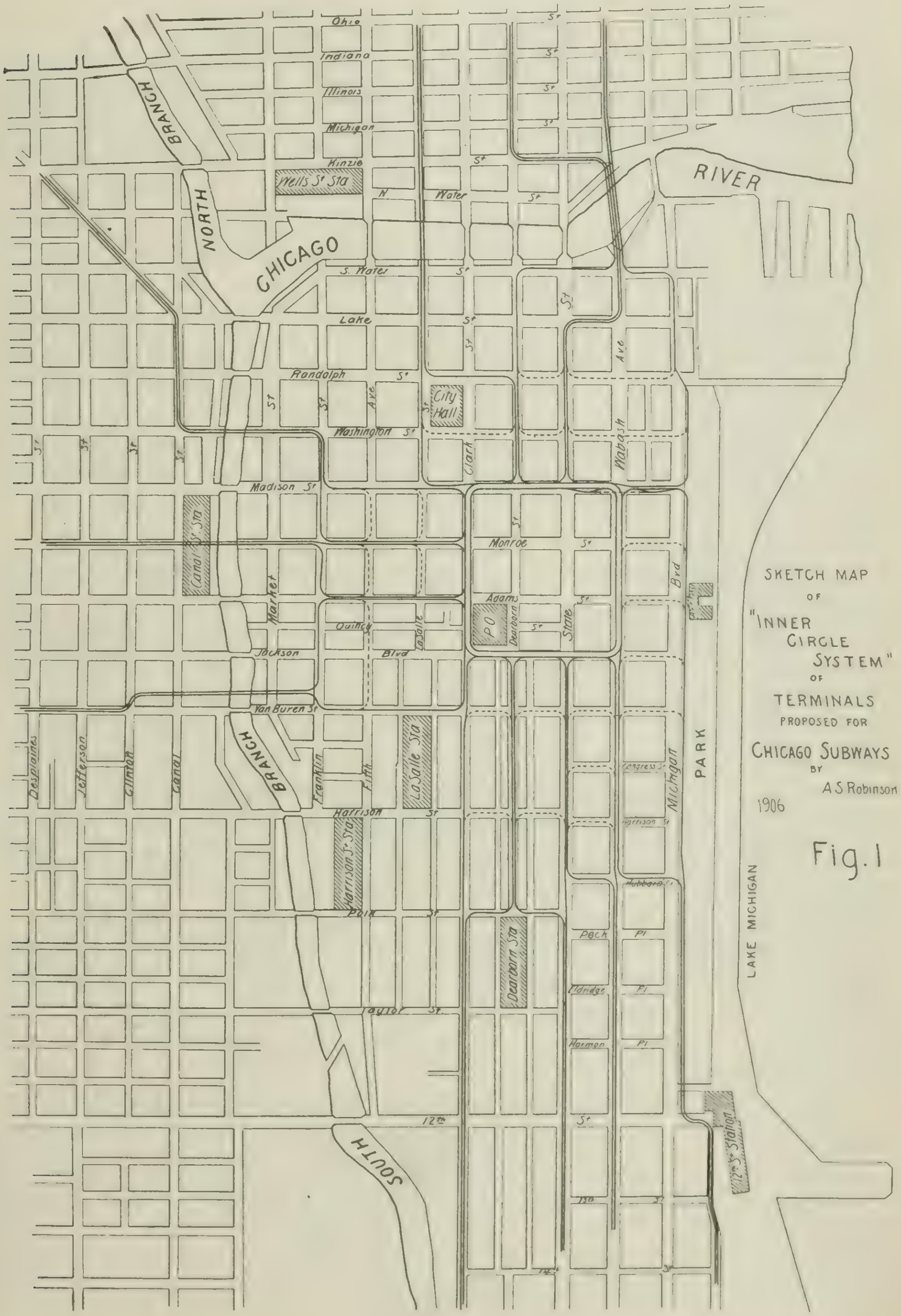
The present trouble with the surface and elevated systems is not that the traffic cannot be brought into the terminal district, but once there, it cannot be handled rapidly enough with the present accomodations, to prevent congestion. It is not alone the present that must be provided for, but a growth and a density of population that seems almost incredible when one stops to estimate it. So that the system adopted, whatever it may be, must be capable of expansion, if possible, wherever and whenever required, by simply an addition to the plan already in operation, and that without its destruction or serious disturbance.

Therefore the problem of bringing the numerous street car lines to their objective point, the business district, is not more vital to the success of the transportation question than the distribution of the terminals, when once the lines have reached that area, because the success or failure of the transportation problem depends upon the terminal system adopted.

Under normal conditions, the greatest congestion is not at "way station," but at terminals, and an analysis of this condition reveals the fact that where the rolling stock can be kept most nearly in continuous motion, the nearest approach to the ideal terminal obtains. At all the great passenger handling points, the loop terminal is adopted where possible, or approximated, where the conditions will not permit of its adoption.

Experience has shown that the loop terminal is the most effective of all forms, and no other should be considered in Chicago's great

under-ground passenger railway system, than which there should be no finer in the world, for we have the whole field before us, practically untouched, and unhampered by geological or topographical prohibitions, or engineering difficulties, as viewed from the present standpoint of the profession.



The plans herewith submitted embody in the greatest measure, the ideals of a perfect terminal. This plan contemplates a subway surrounding any given number of blocks in the down town district. In this case, for illustration, the 12 blocks bounded by Jackson, Wabash, Madison and Clark.

In this subway there would be two belt tracks separated by a passenger platform. The inner track would be used simply as a transfer track. The cars used on this, would be open on the platform side, but closed on the other, and be run in the opposite direction to those on the division loops. There would be transverse partitions dividing these cars into small areas, to prevent the surging of the passengers when starting or stopping. There would probably be seats along the back wall of the car, for those who desire to use it for a trip of more than a couple of blocks. But for those passing to a nearby division loop station, it would be expected that they would stand. This car would be in effect, a section of a moving platform, that would stop and start instead of having a continuous motion. I have canvassed the question of using a moving sidewalk, and believe the best interests of the public would be served by a number of cars as I suggest, to be put on or taken off the inner track as the needs of the rush hours demanded, especially in view of the fact that the "better half" of the population would insist on getting on or off a moving platform backwards, as they still do with street cars.

The platform between the two tracks would be continuous, thus making it in this case twelve blocks long.

The end sections or tangents of the loops of each division line, those parts that are parallel to the inner circle, and separated from it by the platform, are all connected up, and form the second or outer track of the subway. By means of this track, through car service can be maintained between the different divisions of the city, without in the least interfering with the perfect operation of the loop terminals of the independent divisions, because on this track, all the cars of the division lines entering this loop subway, run in the same direction.

Simplicity of arrangement is attained, because the main lines come into the business portion of the city and leave it in the most direct manner. The whole system of tracks down town can be easily understood by everybody. This simplicity of arrangement makes simplicity in operation possible, because each division line terminates in its own loop.

The operation of this loop system must not be confounded with the method in use at present on the elevated loop. In this "Inner Circle System," each division line terminates in its own loop, the operation of which does not in any way interfere with any other line, and neither do the cars of any other line interfere with this, while in the present elevated system the cars of all the divisions pass around the same loop, and each interferes with all the others by cross-

overs and grade crossings. In other words, it is the difference between the use of individual loops for each line, and the use of a single loop for all the lines. Even in case of an accident blocking any division loop, or in the Inner Circle Subway, it would not interfere with the operation of any of the other division lines.

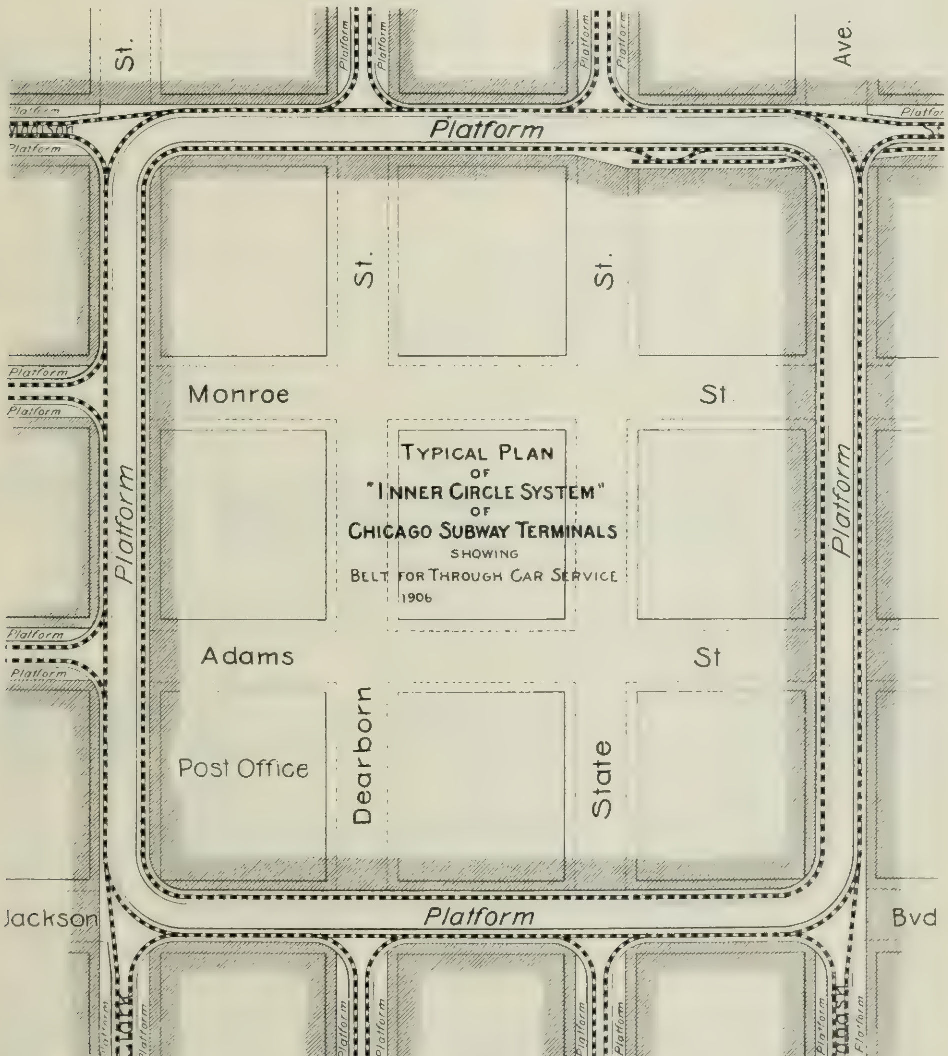



Fig. 2

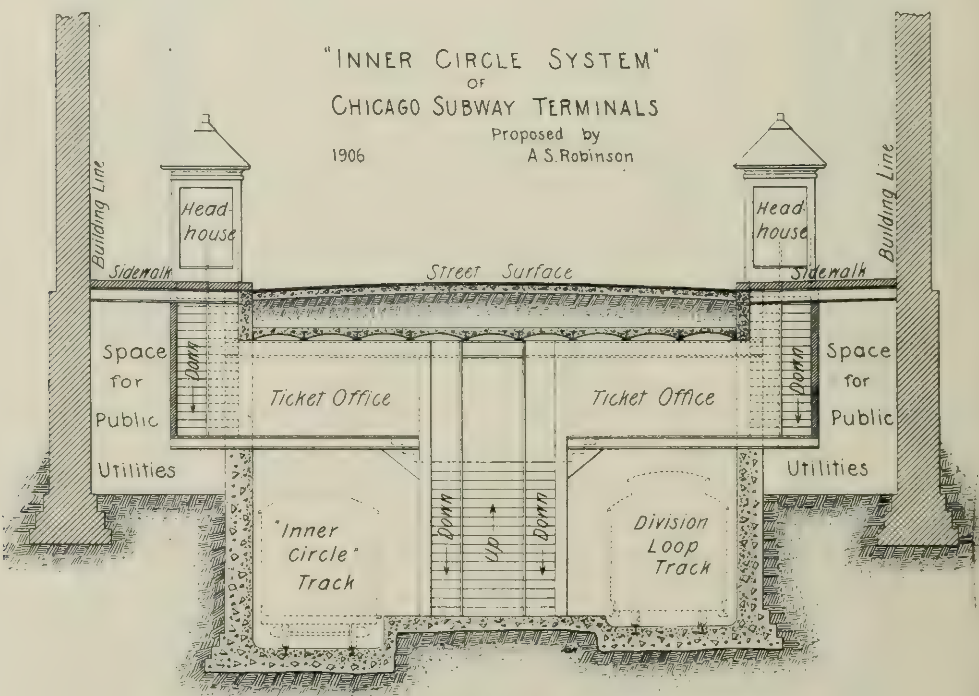
In this plan, curvature may be reduced to the minimum, in most cases to only the 360 degrees necessary to form a loop, and long tangents are the rule, reducing the wear on the rolling stock, and increasing the comfort of the passengers.

Accessibility is accomplished by so covering the down town district that the maximum distance to walk to enter a subway is one and a half blocks. The field being unoccupied, it is possible to design the subways so as to occupy the streets to the best advantage, and to accomplish this, the dominating idea should be to make every

other utility subordinate to this. Chicago's passenger traffic must be the first consideration.

Then follows its safety. In this system there is no grade crossing. In this way alone can the safety of passengers, equipment, rapidity of service and absence of congestion be accomplished. This is a system of absolutely no grade crossings, as all cars on the connected tracks run in the same direction, and each division is independent of the others.

Through car service is easily accomplished by means of the outer track in the loop subway, which is composed of the division loops connected up to form it, thus taking all through traffic off the surface of the streets down town.

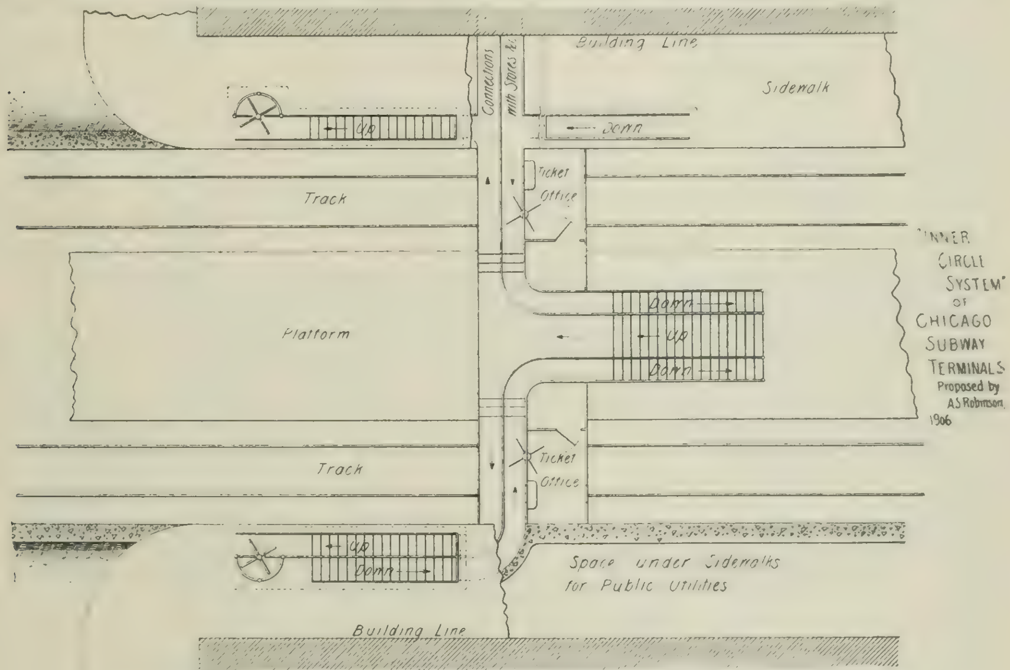



Typical Section of Loop Subway
Fig. 3

The passenger entrances to the subways may be all at the edge of the sidewalks anywhere along the subway, hence may be as numerous as the traffic demands, and not necessarily limited to street intersections. Entrances may also be had from railroad stations, office buildings, theatres, stores, etc., thus eliminating another element of surface traffic.

As none of the subways would come to the surface of the streets in the down town district, there would be no tunnel approaches in that area. The existing approaches would all be closed and the streets restored to their normal condition. To save the street area at the points where the subways would come to the surafce, the plan to purchase private property for the tunnel approaches is recommended.

There is but one level in this system and that will be as near the surface as the conditions of street surface, drainage, and the underground utilities will permit, with a minimum depth of about 18 feet. Thus it will be seen that there will be a less number of steps to reach the platforms, than are now required at the elevated stations.




Typical Plan of Loop Subway
Fig. 4

In providing for express train service, after leaving the loop, these tracks can be carried to a lower level until the local tracks come to the surface, at which point the express tracks would come up to the upper level and continue on this, to the limit of the express service zone, at the minimum depth below the surface if desired. While the necessity for this service is not apparent at present perhaps, it will only be a few years untill the demand for it will be made in no uncertain voice. It needs but the initial move to be made by one of the lines, when the patrons of all the lines will appreciate the advantages, and require its installation.

At the corner of Wabash and Madison is shown the connection between the inner loop and the outer systems. This is indicated here as being accomplished by turning out of the Indiana Ave. loop (and also by a cross-over), passing under the outer and inner circles, coming up and connecting with the inner belt line by means of a turnout and a cross-over, enabling cars to be placed on or taken off, without stopping, changing direction, or running against the direction of the movement of the cars on either track.

In the article in the *"Street Railway Journal"* of July 11, 1903 on this subject, a grade crossing was indicated at this point, and it was stated that this might be eliminated. In the above plan it has been accomplished.

As the Chicago River will always be a handicap or barrier to the expansion of the so-called "down town" district, to the north and west, it is urged by students of the problem that the business area of Chicago must extend to the south, and it becomes necessary upon this hypothesis, to provide any system of transportation, that is designed to serve this area, with the means or the possibility of extending its service at least in that direction. Besides this, it is apparent to all that the area south and east of the river, will and must be, very much more densely occupied before the limit shall have been reached. In view of this rapid increase in area and growing density, it becomes necessary to look a long way into the future, and to provide if possible a means whereby any system, even if it does not meet all the requirements, will at least, not be a handicap to this growth, nor to the introduction of another system that may be developed as the traffic demands.

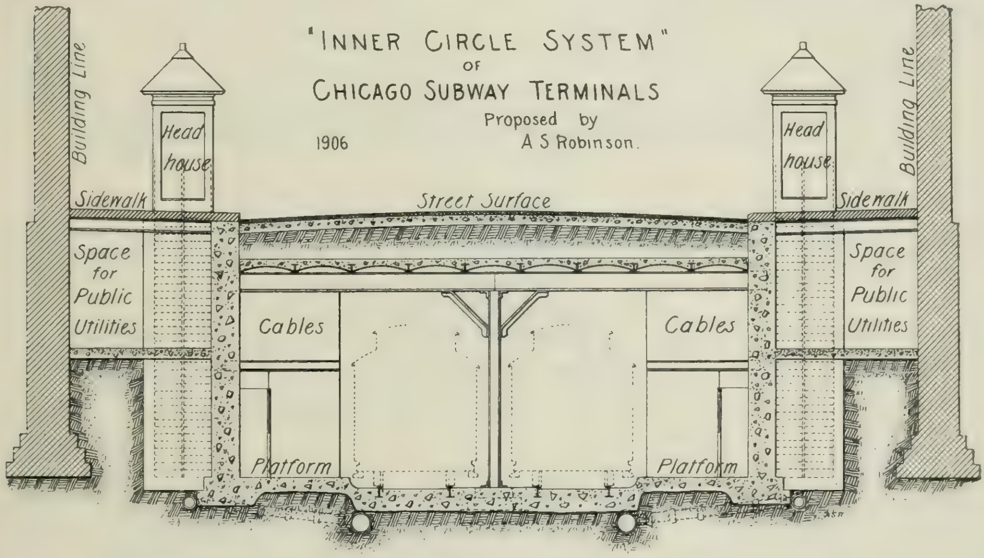
To meet these requirements, I have introduced the additional cross-overs, or loop ends shown by the broken lines on the map, passing from one side of the loops to the other, on the cross streets. These tracks may be single at first, perhaps, and doubled when the traffic demands it, provision being made for doing this, when the work is first done. These tracks would also serve the purpose of preventing a blockade, in case of an accident on or near the inner loop.

But their principal object would be to sufficiently divide the traffic with the head of the loop, and thereby prevent congestion, thus enabling the lines to increase their loop capacity, which means of course an increase in the capacity of the whole system. For the capacity and efficiency of any line to handle its traffic, depends upon the rapidity with which it can receive and discharge passengers at its most congested point. The object of these additional heads, is to enable the cars to be handled so rapidly in the down town district, that there will be no reduction of speed on the main line, outside of this district.

A little study of the map will show that this loop system, once inaugurated, can be very easily modified in such manner as to meet the requirements of areas not specially provided for or for changes in conditions not apparent at present. For it is not intended that this system shall be limited to the arrangement as here shown, but rather that this plan shall be as an illustration, and for the purpose of this article. The underlying principle of the whole scheme is the idea of *an inner loop transfer track, surrounded by an outer loop, composed of the connected loop ends of the diverging lines, and separated from it by a continuous platform between them.*

On this map there are shown three lines from the North, three from the West, and four from the South, but it is evident that by a little different arrangement, with the same number of blocks inclosed, 12 lines could be brought into the Inner Circle, and giving to each the length of a block on the subway platform, for the handling of its traffic in the transfer subway.

The method of construction should be that of the "cut and cover," the "core" remaining to be excavated later, and hauled to the Grant Park filling by tracks laid in the tunnels of this system as fast as the material was removed. It is expected that this plan would be ample, and that it would not be necessary to have recourse to any outside system.




Typical Section of Main Line Tunnel.
Fig. 5

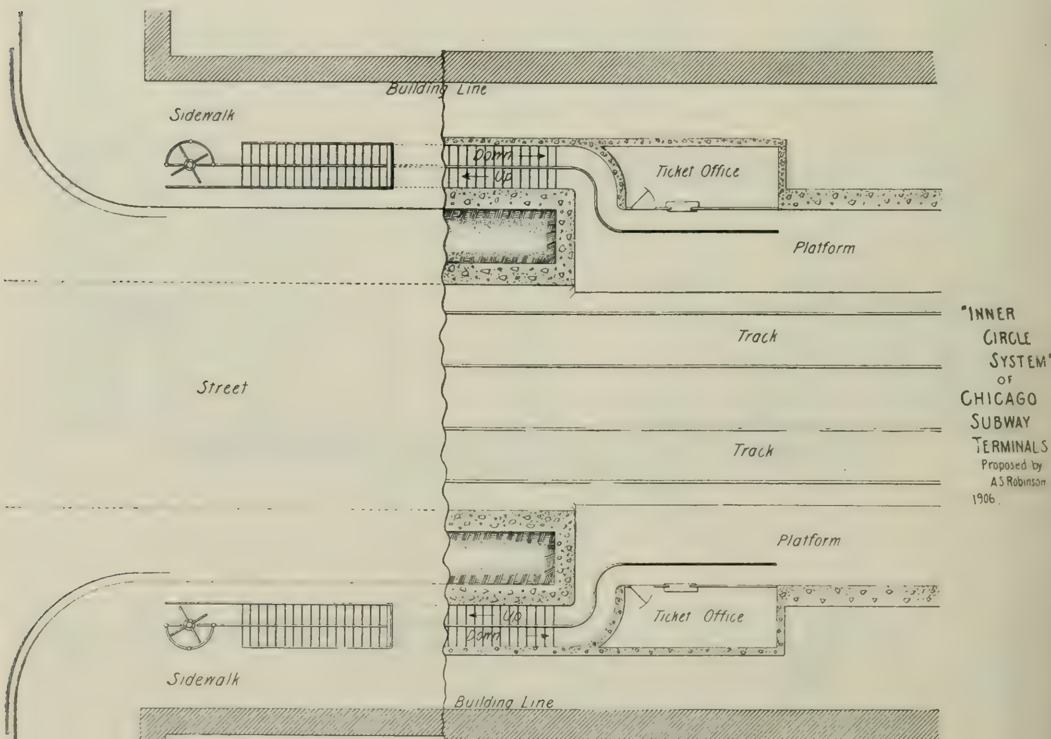
The disposition of the underground utilities, drainage, ventilation, closing of tunnel approaches, and the disturbance of the streets during construction are matters common to all the subway schemes.

The features wherein I believe this "Inner Circle System" excels, are; the greatest possible capacity for the limited area; all subways to be on the high level, thus giving least stairway distance; the possibility of easy through traffic arrangements; the unification of all street railway systems under a single operating management, at least so far as the transit through the down town district is concerned; the safety of passengers and rolling stock; simplicity of arrangement whereby its operation is easily understood; simplicity of operation for each line operates its own loop; rapidity of service, for it is possible to operate on the least possible headway distance; accessibility since the subway entrances may be located at as frequent intervals along the street as the traffic demands; and above all the total absence of grade crossings; and the highly important feature that all cars of the connected systems move in the same direction, thus securing absolute immunity from head end collisions, and a majority of other classes of accidents.

The plan to be followed in the organization and financing of this project should be along the lines of that adopted in New York.

In the New York Rapid Transit subway, it was only necessary to provide for the rolling stock of that company, while in Chicago the

subways must be built with the view of handling the cars of every division and system in town, except of course the cars of the elevated roads. For this reason the platforms used by all the division lines should be no higher than the first step of the present street cars. On the "Inner Circle," however, the transfer track should be depressed sufficiently to allow the floor of the car to be on a level with the transfer platform.




Typical Plan of Main Line Subway
Fig 6

The completion of a successful system of subways for Chicago would mean the removal of a large part, if not all, of the street car traffic from the surface, thereby leaving the pavements to their more legitimate use, that of vehicle traffic. This, of course, would be an ideal condition and should be striven for. With this object in view, all tracks not in use would be removed, and all tracks that would be abandoned after the opening of the subway for traffic would be relaid provisionally, with the object in view of their ultimate removal. If in the future, then, it should become necessary to augment the capacity of the subways by the addition of surface systems again, the problem could then be handled as an entirety and treated in a comprehensive manner as a whole, using a modified form of the "Inner Circle" idea, perhaps, in so far at least as to bring the division lines to an approximate center and terminate them in the business district by loops, without attempting to cross to the opposite side of this area. This plan would eliminate the stub-end terminals and surface grade crossings, which now, more than anything else, operate to reduce the

effectiveness of the present surface terminals. The result would then be that the surface systems in the congested district could be operated in harmony, economically, and to advantage, instead of as an aggregation of independent and unrelated units.

But these ideal conditions, which, however, are all possible, must be brought about by careful, painstaking and thorough study by experts in their respective spheres. Results obtained by popular clamor, immature consideration, and makeshift or temporary expedients, should not be permitted, for these results can only have the effect of handicapping the complete and ideal solution.

---

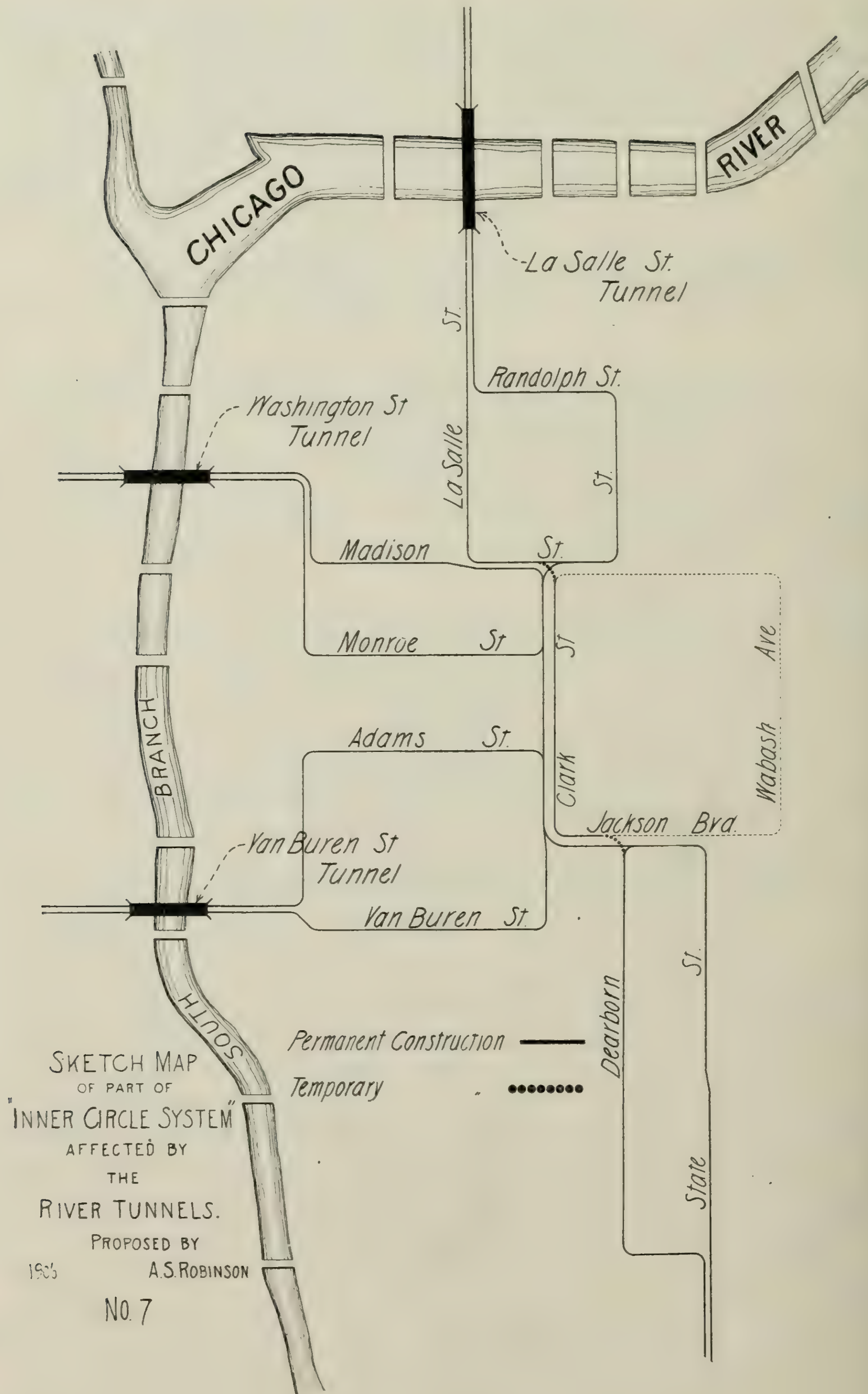
Since the preparation of the foregoing paper the Council Committee on Local Transportation has requested and received from Mr. Arnold a report supplemental to that of 1902. This later report treats of the question of subways, and recommends that the river tunnels be reconstructed in such a manner that they may be utilized without delay, as a part of a comprehensive subway system.

The act of lowering the tunnels will make the approach grades steeper, if connections are to be maintained with the surface tracks, as they now exist. As these grades are now about the maximum, the logical thing to do would be to either extend the approaches to maintain the old grade, or better yet, to plan to close the openings in the street surfaces, as soon as practicable, and arrange to terminate the tunnel approaches in subways. By this means the grades would ultimately be reduced, and a beginning be made on a system of subways.

But before these subways can be extended, or even their depth below the street surfaces, which determines the approach grade of the tunnels, can be established, it is imperative that a comprehensive general plan of subway terminals shall be adopted for the accommodation of the traffic in the downtown business district.

In addition to the requirements of this system, whatever it may be, that it not only accomodate the traffic upon its completion, and that it may be flexible enough to be extended to accomodate the growing needs of the city, it shall be possible to build the least amount of subway, at present necessary to accommodate the river tunnel traffic, and yet to have that which is built, a part of the completed system without the construction of unnecessary tunnels or the abandonment of any works that may be built for this tentative use.

Since the three existing tunnels would naturally, from motives of economy, be incorporated in any plan of subways, the reconstruction of them forces a decision in favor of the commencement of the construction of a system of subways, and that portion of the subways that would be immediately affected by the three tunnels, would logically be the portion first built.


CHICAGO
RIVER
La Salle St.
Tunnel
La Salle St.
Randolph St.
St.
Washington St
Tunnel
Madison St.
Monroe St
Adams St.
Clark St
Wabash Ave
Jackson Bvd.
Van Buren St
Tunnel
Van Buren St.
Dearborn St.
State
SOUTH
BRANCH
Permanent Construction
Temporary
SKETCH MAP
OF PART OF
"INNER CIRCLE SYSTEM"
AFFECTED BY
THE
RIVER TUNNELS.
PROPOSED BY
A.S. ROBINSON
NO. 7

By reference to Figure 7, it will be seen that in the "Inner Circle System" the lines using these tunnels terminate in three loops entering the transfer subway in Clark and Madison streets. And to inaugurate this tentative arrangement it would only be necessary to build these loops and join them by that portion of the transfer subway which connects them, using the inner track of the transfer subway as a return connection between the loops for routing through cars only.

This would be of course only a comparatively temporary arrangement as far as the use of the inner transfer track is concerned and would only be used in this manner until such time as the remainder of the loop became an accomplished fact. Upon the completion of the transfer loop then, this track would be devoted to its original purpose, that of a passenger transfer.

In order to place this plan upon an equal basis for comparison with Mr. Arnold's recommendations in his recent report, it is only necessary to add a fourth loop on the south side, say of the State street lines, and connect it with the other three by that portion of the transfer subway that intervenes, as shown by Figure 7.

While this fourth or State street loop is not necessary for the solution of the inauguration of the subways affected by the tunnels, and possibly not yet required by the demands of traffic, it would establish an underground interchange of traffic between the North and South sides and remove all the street car traffic using the three tunnels and State street from the street surfaces and form the beginning of a universal transfer system, which would be effective up to the capacity of the division lines.

This temporary plan of course would not make the track arrangement as simple as the completed system, but all the work done to accomplish it, would be a part of the ultimately completed plan. And would not require the abandonment of any portion thus used. except the two temporary connections between the transfer tracks in the completed tunnels.

In addition to this, the remaining loops of this system could be built from time to time as conditions demanded, each loop being added to those in operation, all in the line of the original plan, by simply the construction of the division loop and such portion of the inner circle transfer tunnel as necessary to accommdate it. This method could be pursued till so much of the transfer tunnel was built as to warrant its final completion, when the transfer service could be inaugurated and the system as a whole would be working on the contemplated plan.

It will be observed, however, that upon the completion of this tentative plan one-half of the transfer tunnel will be built, which might act as a strong incentive to the other companies occupying the surface, to acquire subway terminals also, and completing the transfer subway.

Recently a movement has been made having for its object the

building of a side track in Clark St., at the Post Office, for the accomodation of the street railway postal service which has grown to be an important factor in the street car traffic of Chicago. In the "Inner Circle System" this might be economically and satisfactorily accomplished by building a second subway under the passenger tracks and platform in the streets contiguous to the Post Office and connecting it with the outside of the tracks in the outer belt of the transfer tunnel track, thus leaving the platform and passenger track intact, and at the high level which is their proper location.

There would thus be eventually a Post Office side track for its exclusive use on the lower level which would be no detriment, with no grade crossings, and the only interference with the passenger tracks would be the switches of the turnouts. As these would be of the same character as the other switches, and operated by the same system, the objections to breaking the continuity of the tracks would be reduced to the minimum.

In the above so-called temporary, as well as in the completed system, all the recommendations and suggestions of Mr. Arnold, in his recent report as well as that of 1902 have been met. And in addition the greater recommendation, nay, demand, that there be but one high level subway, without grade crossings is possible of achievement. It is to be observed, however, that this doesn't apply to the tentative plan here suggested, because in adapting the inner track to the purpose of return traffic it would be necessary to put in two cross over tracks and crossings to be used only until such time as the completed transfer tunnel could be put in operation. While this is true, these crossings are located only in the tracks over which through cars are routed. The number of cars in this service being less than in the division traffic, the probability of accident is very much reduced, even during the time that these provisional tracks and crossings would be in use.

In this initiative plan herewith submitted there is about 70 per cent. as much tunnel required to be built as by Mr. Arnold's plan, to accomplish the same results. This plan also saves the long trip over to Michigan Avenue and return for the west side cars, which is objectionable in any plan both from the passenger's point of view and that of the street car manager, hence from these two factors, and the added advantage of the high level tunnel, economy suggests the plan herewith submitted.

## DISCUSSION.

*B. J. Arnold,* M. W. S. E. (by letter)—It is a source of deep regret to met that I am unable to be present at the reading of Mr. Robinson's valuable paper entitled "The Proposed 'Inner Circle' System of Chicago Subway Terminals" as it is a carefully prepared contribution to a subject of great importance to the citizens of Chicago.

Inasmuch as my associates and myself gave the transportation problem for the City of Chicago serious consideration some years ago, which resulted in a somewhat exhaustive report to the City Council, wherein numerous recommendations regarding different method of improving the transportation systems of the city, many of which have since been adopted, I am especially pleased now to have the subway question, which was one of the principal subjects then considered, brought so prominently before the Society for discussion.

While I have always held and firmly believe that any transportation system for the City should embody the through-routing principle, thus tending to lengthen the business district North and South and extend it Westward, as distinguished from the loop system, which tends to contract the business district, and while I firmly believe the plan recommended by me in my report of 1902 to be the best one, it is possible that neither of the subway systems therein recommended may be the correct one to adopt, for only by a comparative analysis of the systems therein outlined with those originated by others, will the most desirable solution of the problem be found. I am also glad to have the plan submitted by Mr. Robinson discussed, for the reason that it differs radically from the subway systems outlined by me. In this connection I wish to state that at the time of the preparation of my report of 1902 I laid out a very elaborate loop terminal system, similar to the one Mr. Robinson describes, except that instead of operating the cars upon the "inner loop" I proposed to operate a movable sidewalk and keep it in continuous operation, alongside of which the trains ran at the same rate of speed as the platform of the movable sidewalk, thus enabling passengers to alight from the trains on to the platform without stopping the trains. I spent considerable time upon it and finally concluded that it would tend to congest the business district rather than extend it, and that the feasibility of operating such a system was questionable, and I therefore abandoned the idea and eliminated it from my report before publication. The criticisms, so far as the element of danger to passengers is concerned, which I applied to my scheme, would not apply as effectually to Mr. Robinson's plans, for the reason that he proposes to operate cars on the "inner loop" instead of a movable sidewalk and to stop all trains when passengers are transferring. This very restriction, however, greatly reduces the capacity of the loop over the plan I proposed, and I am of the opinion that it would so restrict the capacity that it would be found impracticable to handle the number of cars necessary to take care of the passengers during the rush hours. In this connection I also wish to point out that both subway systems, known as No. 1 and No. 2, outlined in my report utilize, to the extent thought necessary by me, the loop system, but only for returning surplus cars from any particular district of the city, the majority of the cars running through.

Fundamentally the systems recommended by me and the one advocated by Mr. Robinson differ as follows: His makes the loop principle the fundamental feature, with the through-routing scheme as supplementary. In my plans the through-routing scheme is fundamental and the loop feature supplemental.

I hope the discussion will be entered into earnestly by all present, and that the relative merits of the various plans will be thoroughly brought out.

*C. V. Weston,* M. W. S. E.—Mr. Robinson's paper opens for discussion one of the most interesting and complicated problems in local transportation, that engineers and others skilled in the construction and operation of street railways have been called upon to solve.

So far as the speaker has been able to determine there is no other city wherein there exists conditions affecting local transportation which are parallel with the present conditions in Chicago. The present unsatisfactory situation in respect to the transportation system of this city is primarily due to the course of the Chicago river by which the city is divided into three separate divisions, and from the earliest period in the development of the city and its local transportation system privileges for the construction and operation of street railways have been granted for the separate divisions to separate companies. Naturally each division ownership, not being in any manner interested in the operation of any other division, guarded against the invasion by competing interests of a territory which it considered specially its own. They laid out and constructed extensions and new lines as there arose the necessity or the excuse for building them, until there was developed three extensive systems of transportation operated with a view to perpetuating the travel in each division over that division's lines toward a common point. This was to the detriment of the city considered as a whole, and to the manifest unfair advantage of the small area designated as the business district which has grown around a common center toward which all lines of transportation have converged.

The congestion on the streets of this business district has increased very rapidly with the increase of the city's population until now the conditions have become intolerable and we are facing the problem of providing some remedy which will relieve the situation.

The speaker is in full accord with the statement of Mr. Robinson that whatever is done toward improving existing conditions should be the result of careful, painstaking and thorough study by experts in their respective spheres, to the end that the resulting system of local transportation would be a homogeneous one, operated under a single management and in such manner that the best interests of the city considered as a whole would be served. Moreover, nothing should be done in the way of permanent work to improve the existing conditions which does not have reference to the unification of the entire local transportation system under a

single operating head. The local transportation of passengers in cities, should be a monopoly whether the facilities be municipally operated or are operated by private enterprise under contract with the municipality; and the speaker firmly believes that, if in the early days of local transportation in Chicago those who were charged with the administration of municipal affairs had been endowed with wisdom to make the street railway system a monopoly and to continue its operation as such, an entirely different method of operating the cars over the system would have been adopted, divisional operation would have been eliminated, the business district on the east side of the city would long ago have been elongated far beyond its present northerly and southerly limits and the growth of other business centers would have progressed to such an extent that the aggregate value of property in Chicago would have been enormously greater than it is at present, although some of the abnormal values which prevail in the existing downtown business district would probably never have been created.

It seems to the speaker that the first element of the problem to be considered is not the creation of terminal facilities in the downtown district but to decide the question of whether the present conditions shall be perpetuated and merely palliative measures be adopted to meet existing demands from some quarters for increased terminal facilities for the surface street railways, or, whether under a unified system of operation the necessity for such terminal facilities shall be largely eliminated from the problem by some rearrangement of and additions to the present tracks, the adoption of a different method of operating cars over the tracks of the unified system and the possible addition to the present plant of subways in certain localities when the necessity for them really arises.

The ideal transportation system for a large city would be one enabling a passenger to make a continuous journey, without change of cars, between any two points on the system. A complete realization of this ideal is quite impossible on any large system. The nearest approach to it, however, may be found in long narrow cities like New York. That system of transportation which fulfills the ideal in the least degree will invariably be found in cities where the transportation lines are constructed on the radiating plan, like Boston, Brooklyn and Chicago, in each of which will be found a common point where all lines of traffic concentrate and which is the objective point of its population.

Transportation lines in cities are, or should be, operated in the way which will provide the most comfort and convenience to the passengers, and which will give them the most direct, speedy and safe transportation to their destination, if possible without change of cars.

Experience has taught those charged with conducting transportation in cities built on the radiating plan, where the largest part of the traffic is toward a common point, that by establishing sep-

arate lines leading directly from the various centers of population to the point toward which traffic converges, and by apportioning to these various lines the available cars according to the density of population along each line, the most satisfactory results can be obtained in respect to supplying speedy, comfortable and convenient service.

The most effective method of operating cars or trains, at the point common to all lines, is by means of loops, because where traffic is unavoidably congested, more cars can be operated over a loop terminal in a given time than can be operated into and out of any other type of terminal.

Where it is possible to provide a separate loop for each line entering a terminal district, terminal facilities equal to the ultimate capacity of the main line tracks is assured. It is seldom, if ever, possible to provide a separate loop for each line entering a business center, therefore, several lines must make common use of one loop with the result that, in time, owing to the natural increase in traffic, the ultimate capacity of a loop is reached and other disposition must be made of those cars coming from the main lines that cannot be accommodated on the loop.

Under the present system of divisional operation of street railways in Chicago, the conditions just described in respect to the ultimate capacity of terminal facilities being reached, obtain today in the downtown district.

The conditions that have grown out of the building of the city around this small center making it the objective point for the whole population, must of necessity continue indefinitely, but the expansion of the business district is assured. As Mr. Robinson has suggested in his paper, the river will always be a barrier to the expansion of the so-called "downtown" district to the north and west The present business area of Chicago must extend southward, and any system of transportation that is designed to serve this extended business area should provide for the extension of the service through the district to its southerly boundary of all lines of transportation entering that district, and it should be accomplished in a manner that would minimize the necessity for transferring passengers from the cars of one line to those of another line. This can be accomplished only by the subordination of terminal facilities in the downtown district to main line traffic, which is the reverse of the plan proposed by Mr. Robinson.

For any comprehensive solution of the problem before us the through routing principle must be recognized as being of the first importance and in the business district through routes should be substituted for terminals, wherever possible, for both the surface lines and subways when they are constructed. A system of subways should be, and eventually must be, built in Chicago to accommodate street car traffic and relieve the surface congestion in the downtown district. The subject of subways has been brought

so prominently before the people in recent years that it seems to the speaker there is little danger that the sub-space of the streets will be given up for other uses to the exclusion of subways for street car purposes.

While Chicago, with reference to the present method of operating its local transportation system and to the situation of its principal business district, may be considered as being laid out on the radiating plan, a glance at a map of the city (especially one on which is indicated the distribution of the city's population) will show that Chicago is really a long and narrow city and that the longest streets which lie for the greatest distance through the most densely populated areas are north and south streets; these constitute the natural trunk lines for a local transportation system; and it seems to the speaker to be quite clear that with a unified system of transportation, operated under a single management, the main routes would be along the north and south streets and that cars would be run as far as possible in one direction, especially on those north and south lines which pass through the downtown district.

A well arranged system of through routing cars in the business district on parallel lines will provide the maximum capacity for bringing passengers into and taking them out of the business area, but we must recognize the fact that the downtown district is the objective point for a very large portion of the city's travel, especially night and morning, and that, during the rush hours, a large number of cars would be operated into and out of the business center as they are operated now from all divisions of the city. This could be accomplished in the most effective manner by connecting the parallel lines with cross lines forming loops, so situated that cars coming from the north routed to the downtown district only would pass through that district to its southerly limits and return north from that point, and cars coming from the south not routed through would pass through the business district to its northerly limits and return south from that point. It is not a difficult matter to so arrange tracks and route cars over them in such manner that a passenger by selecting his car or route would be taken within reasonable proximity to any point within the business area.

Such a system of tracks and loop connections, if both surface and subway lines were utilized, would provide the greatest capacity which it is possible to develop within the downtown district, far in excess of any system of loops that can be devised for that district. Moreover it is susceptible of unlimited extension without in any way disarranging either the structure or the method of operating cars.

The speaker estimates that the ultimate capacity of the double loop proposed by Mr. Robinson would not be more than 60,000 passengers per hour. This determination is based on the assumption that cars could not be operated on a headway of less than 15 seconds for each loop track, which would give 240 cars per hour

passing a given point on each loop. Assuming further the capacity of each car at 60 passengers, that the average distance traveled by each passenger would be a half circuit of the loop, and that the cars would be loaded to their full capacity during the entire hour, each car in making one circuit of the loop could take on and discharge 120 passengers, and the 240 cars making one complete circuit of the loop in one hour could convey 28,800 persons. The capacity of both loops would be 57,600 passengers.

It is quite evident that should Mr. Robinson's plan for an inner circle loop terminal be adopted, its capacity would be overtaxed at the very beginning of its operation, and it would constitute a perpetual bar to the development of any comprehensive system of through routing cars.

There is nothing new or original in the ideas advanced by the speaker tonight; everything that he has said was brought out in the first "Arnold report" to the Local Transportation Committee of the City Council of Chicago. In the preparation of that report the speaker had the pleasure of being associated with Mr. Arnold. The object of this discussion being to place before the membership of the Society a phase of larger subject which seems to the speaker to be of the first magnitude; namely, "through routes," and with which the installation of such terminal facilities as has been proposed by the author of the paper present this evening would seriously interfere.

*Mr. H. B. Fleming*: I have been very much interested in Mr. Robinson's valuable paper, and also the discussion presented by Messrs. Arnold and Weston.

I quote one sentence in the paper,—"The ability of any railroad system to handle its traffic depends more than anything else upon its terminal facilities." In looking over the plan suggested in this paper it seems to me that, as has already been brought out by Mr. Weston, the "Inner Circle System" of terminals would be inadequate to handle the traffic which we expect to get in this district in the next five or ten years. In fact, I believe it would be taxed to its utmost capacity at the present time.

I am of the opinion that in considering a subway system for Chicago the lines running under the north and south streets (or the trunk lines as we generally designate them) should be "through" lines. Some of the cars possibly could be turned on loops which would be located north of the business district, and others on loops located south of the business district. The lines running into the business district from the west should be taken care of by loops in the district itself, and they should all be connected (or some of them) in such a way that "through" routing could also be obtained from the north and south divisions to the west division of the city.

One other suggestion I would make. If it is desired to perpetuate the downtown terminals such as we have in use on the surface at the present time, (of which the plan presented tonight is only a

modification) we could accomplish the same results and do away with at least one transfer in the business district by looping the cars on one street,—do away with the inner circle entirely; have the north division and south division cars looped on one street, and thus have the same capacity as that provided by the "Inner Circle" plan without any additional transfer in the business district.

*George Weston,* M. W. S. E.—The paper presented by Mr. Robinson deals with a subject that should be of great interest to every citizen of Chicago, but is of especial interest to some of us here tonight, for the reason that it treats of a subject that has been part of our daily occupation and work for a number of years past, viz.: to find a correct solution of the transportation problem of the City of Chicago. In our study of the subject we have arrived at a somewhat different conclusion from the one presented by Mr. Robinson, and we enter the discussion with the view of assisting as far as possible in paving the way to the best solution of the same.

As has been stated before this evening, we differ from Mr. Robinson in the practicability of making the loop system the essential part of a comprehensive system of transportation to provide for the future as well as the present needs of the city. The question, in my judgment, resolves itself into a discussion of a "loop system" compared to a "through-route system" as its predominating feature.

Among the several factors that must enter into the problem the three following, in my judgment, are the most important:

First: The system should be planned so as to permit the unlimited enlargement of what is known as the downtown business district.

Second: To be planned so as to deliver its passengers from any division of the city to any point in this enlarged district as far as possible without the necessity of transferring from one car to another.

Third: And so planned as to permit the greatest number of cars possible to pass through this enlarged district from and to, all divisions of the city.

I do not think anyone will question the correctness of Mr. Robinson's statement regarding the practicability of the application of the "loop system" of terminals where the delivery of the passengers is to one objective point, such as a fair ground or park, or other central point where it is desired to deliver a large number of persons in a short space of time upon cars operating under comparatively close headway. Under such conditions the loop system is ideal, but considered in connection with a complete transportation system to serve the entire city of Chicago, the application of the "loop" in any capacity but as an auxiliary to the main principle, in my judgment, is wrong, and that a system with the through-

routing of cars as the main feature of the system, solves the problem in a more comprehensive and satisfactory manner.

The article describing the proposed terminals for the contemplated Manhattan Bridge, referred to by Mr. Robinson as having appeared in The Engineering News of December 7, 1905, apologizes, in a way, for the application of the loop system of terminals. In this case the through-routing of cars is recognized as being the ideal system. The following is quoted from the article referred to in the Engineering News:

> "The fundamental principle which was evolved out of the Brooklyn Bridge terminal problem is that terminals must be avoided altogether, or as much as possible. In order to enable the bridge itself to be utilized to fullest capacity, the terminals would have to be very large and elaborate; they would need to be double at each end, comprising a terminal for the lines of railway crossing the bridge, and a terminal for the city lines leading to the bridge. Now, of the mass of passengers crossing the bridge, only vanishingly few start from or are bound for the end-point of the bridge, or its immediate neighborhood; the vast majority start from or desires to reach points on the urban transit lines leading to or from the bridge. It follows that the needs of the traffic are best served by combining the urban lines and the bridge lines in through service, thereby avoiding the delay and inconvenience of interchange at the terminals. This arrangement, moreover, rendered unnecessary the large double terminals otherwise essential. In the case of the East River bridges it is not practicable, at the present day to apply this principle fully, but subject to certain restricting conditions, it is carried out as far as possible in the present designs for the Manhattan Bridge terminals.
>
> "The main interfering factor is the fact that the present urban transit systems on the two sides of the river are radically distinct. The Brooklyn surface (overhead trolley) and elevated lines form a single system; the Manhattan surface cars (conduit trolley) are a single system; and the Manhattan elevated lines are another system. The physical equipment, as well as the operating conditions of the Manhattan and the Brooklyn systems are quite different, and above all there is a strong antagonism between the two groups of lines, which would act effectively against either interchange of traffic or mutual invasion of the other's territory. In consequence it was not possible to adopt a complete *"through"* system of operation, but it became necessary to provide a terminal for Manhattan transit at the Brooklyn end, and for Brooklyn transit at the Manhattan end."

Referring to the essential features of a comprehensive street railroad system for the city of Chicago, the necessity of arranging for the enlargement of the downtown business district must be apparent to us all. There can be no doubt as to the fact that Chicago will continue to grow in every way, and at least maintain its present relative position with the large cities of the world, if it does not outstrip and exceed in population some of the larger cities of today. Statistics show that the rate of growth of the city of Chicago has exceeded that of any large city in the world. The average rate of increase in population of the city of Chicago between the years 1837 and 1902 was 8.6 per cent per annum, and for the decade between 1892 and 1902 the increase was at the rate of 4.9 per cent per annum. At the time of the publication of Mr. Arnold's City Report in 1902 a population curve was worked out based upon the actual growth of the eight largest cities of the world, and this curve shows that the annual rate of increase is a decreasing rate, and this information has been termed "the law of yearly decrease on the rate of increase."

Starting in 1902 with a rate of 7 per cent, and applying "the rate of decrease on the rate of increase" this curve shows the population of Chicago in 1952 will be 13,250,000.

The law derived from the eight cities, mentioned above, shows that the average rate of increase per annum for a city of 2,000,000 is about 3 per cent. Starting with this very conservative annual rate of increase for Chicago and applying "the average decrease on the rate of increase" the curve gives the population of Chicago in 1952 to be 5,250,000. It therefore seems evident that in less than 50 years the population of Chicago will have reached the point somewhere between 5,250,000 and 13,000,000. When we realize that with our present population of some 2,200,000 we feel the effects of the contracted business center as represented by what is known as the "loop district," we *must* conclude that any plan of transportation devised today, should provide for the unlimited extension of this business district.

In considering the second important feature referred to,—"the delivery of passengers from any division of the city to any point in the enlarged business district,"—it will be apparent at once that the application of the "loop system," will necessitate the passengers from the Southern districts of the city transferring to other cars at Jackson Boulevard for points North of that avenue, and passengers from the Northerly division of the city transferring at Madison Street for points South of that street.

Referring to the third factor,—"to permit the greatest number of cars possible to pass through the enlarged district"—it would seem to me that it is a self-evident fact that "the greatest number of cars, in the shortest space of time," can be passed through this business district by *through-routing* the cars through the business

district, and have conditions prevail that will afford the least possible chance for congestion.

*Mr. Mason B. Starring*: My personal ideas on the subway question will probably be considered inverted. Mr. C. V. Weston speaks of permitting the vehicle traffic to monopolize the streets, and having the street cars run in the subway. I thnik it is a very unfortunate thing that we have started our subway system wrong; it seems to me the place for the vehicle traffic is in the subway, and that the cars should be permitted to run on the surface (as far as possible) in order that the people may get light, air, etc., unless (of course) a much greater speed could be obtained by the subway arrangement. I believe we should have started this thing by putting our wagons in the basement and retaining the upper story for our cars. However, as we have started wrong, one weak, small voice against all that has been done will be of no avail, and we shall probably descend into the basement.

When Mr. August Belmont was here a few years ago he told me that Chicago would need no subway for a long while; that, in his opinion, the subway should be the last resort; that Manhattan came to it only because it had no other means left. He stated that our surface system was capable of great improvement, and could be developed so as to relieve for some considerable time the congestion now experienced; that the system of elevated railroads could be developed so as to afford a much better system of accommodation than we now have. After that, he stated, subways could be considered. His ideas were generally on the line of "through" routing; that the surface roads could be improved by making the termini outside of the business districts; that through trains should be run so as to give each division of the city a through ride over the other divisions. But this is rather "begging the question" of the paper tonight.

We know that people dislike transfers, and anything that increases the transfer system would naturally be against the trend of public opinion. The loop may however, sooner or later be an auxiliary to the subway system, which Mr. Weston has very ably suggested should have its terminals at the ends or outside limits of the business district.

Mr. Robinson's paper seems to be very closely allied to the trend of the wishes of the people of Chicago today, which seem to be to get to the corner of Madison and State Streets at the same time, all wanting to take the same car and leave at the same moment. Anything that tends to perpetuate and increase the congestion down town and keep people wanting to get to the same spot at the same time, is going to hinder at all times the transportation facilities which any city can furnish. If you can spread out the territory to more equal proportions, and arrange the routing accordingly, you are going to do a great deal toward clearing up the situation. But with this demand for transportation to and

from one point, and one point only. I see no feasible way of handling the problem satisfactorily at the present time.

*Mr. Walter L. Fisher*: I can assure you the last thing in the world I anticipated was that I should be called upon tonight to say anything on an engineering problem. I have nothing to say upon anything which is at all an engineering problem.

I am one of those who at one time had the idea, as stated by Mr. Starring, that I would much prefer to ride upstairs than down in the basement, but I have come to the conclusion that there are certain difficulties in the way of that arrangement. Subways can never be used for team traffic in a central district where this traffic must be distributed over every street to reach the business houses with which this traffic is connected. There would have to be a subway upon every street. I believe we should adopt the method best suited for use in large cities, and particularly in cities like Chicago and New York, which have congested districts, providing some form of elevated or subterranean transportation for the passengers who can leave the subway or the elevated road and distribute themselves to their respective down-town destinations.

There is one thing that impressed me in the very beginning of the consideration of this subject, and that is, while it is an excellent thing always to start with an ideal condition and consider what you would do if you had a completely clean sheet, as a matter of fact the only useful purpose of such a course as that is to ignore it at once when you tackle the problem from the other end, and simply use it as a method of checking up. In other words, we must never forget that we have to accomplish a definite practical result under existing and not under ideal conditions.

I am unable to share at all in the idea of Mr. Robinson that we can, either in the immediate or remote future, remove from the surface of the streets the street cars which now occupy those streets. This is both because of the reason which Mr. Starring has intimated, that the people prefer to ride on the surface if they can do so, and because we shall be compelled to use the surface of the streets as well as subways to accommodate the constantly increasing traffic.

The mistakes which Mr. Weston points out have unfortunately been made; we are committed to certain things by reason of those mistakes; some were due to the City Fathers of the early days, and some were due directly to the gentlemen who were running the local transportation in those days, and who ignored the original wishes of the City Fathers, and induced them to acquiesce in what was more or less a compulsory division of the city. To divisional ownership and operation we owe many of our present ills. But our mistakes have been made, and we are now to work out an existing problem under present conditions.

This brings me to the remark made by Mr. Starring, that we have a long time in which to work out the subway problem. I

regret that I am unable to concur in that remark; nevertheless I will express my own ideas. The situation in Chicago today, and the situation which we are going to confront in the next few years is, that we have got to build a system of transportation which must cross the river to the north and west sides; we must go across either overhead by bridges or under-ground by tunnels. It seems to be the conviction of those most experienced in our local transportation that the method of crossing by bridges is bound to be unsatisfactory; that some transportation must be provided by means of tunnels. There are many reasons for this, one of them being that blockades are less likely to occur; and that many conditions arise where tunnels can be used when bridges cannot be used. We have already three tunnels, two of which belong to the city, and the question is, what are we going to do about them? It has seemed to Mr. Arnold and to me that one thing at least is self-evident; that whether we use the river tunnels or not in the immediate future, whenever we do use them the traffic that goes through those tunnels should not be permitted to come to the surface in the center of the city; that once down the cars must be kept down, as far as possible. We may not be able today to install an ideal transportation system for the reason that it would require a financial outlay which would be prohibitive; but we can at least insist upon the principle I have suggested.

The first thing which has been insisted upon in all of the work of the Local Transportation Committee, starting with the report of Mr. Arnold made in 1902, (and I have always taken pride that I, myself, had something to do with the getting of that report and the selection of Mr. Arnold to make it) it has been the definite policy of the City Council, (which has met with practically unanimous favor) to establish through routes on the surface of the streets. I take it for granted that even if we are now able to take care of all our transportation upon the surface of the streets, as Mr. Belmont thought possible, it is now possible, to establish a certain number of through routes. Many of us have been blinded by the divisional method of operation, and led to think that we are unable to change the situation. Take the cars from the north side, for instance; for certain hours in the morning they come to the center of the city crowded, and then return to the north side empty; while the south side cars come crowded to the center and return empty to the south side. These same cars from the north side could, with no additional expense of operation after discharging their passengers into the centre of the city, run on out to the south side, even though comparatively empty, at no greater expense than to return immediately to the north side empty. The advantage of such an arrangement would be the tendency to spread the commercial district. For instance, if passengers could travel from, say, the north side directly to and through the south side without change of cars, the business district, while at present con-

fined closely within the loop, would tend at once to spread out over a greater area. The same would be true if there were through cars from the south to the north side. Couple with that the possibility of creating through lines from the north and south sides to the west side, and you will have a still greater spreading out of the business district, for the man who wishes to locate a business is not then bound to be as near the center as he can get. We will suppose that the population of Chicago within the next generation increases one-half more than it is now, or suppose it is fairly doubled (which is more likely); the mere increase of one-half means, of necessity, a large increase in the central district of the city. If a business establishment is started south of the present commercial limit, that establishment must work against the current all the while. The present situation is altogether against the development of that establishment. But if we have a system of through transportation then the man who is undertaking to enlarge the central business district by locating his place of business further south, north or west, will have removed from his path difficulties which have been placed right in his way under existing conditions.

It seems to me that Mr. Robinson's plan is defective from the outset, in its inevitable tendency to increase the congestion of the central business district. Whether he selects twelve or any other number of blocks about which to build his central loop, he must select some particular blocks for this purpose. About these blocks, whatever or wherever they are, his central loop at once becomes an iron band, admitting of no natural growth or expansion. It seems to me that is the fundamental objection to the plan. Some minor objections I think might be mentioned. I do not think Mr. Robinson's plan has met the situation presented by Mr. Arnold's last report at all. In the first place we are dealing with a problem that, whether we like it or not, it is a problem in municipal politics as well as in engineering, and I venture the assertion that any proposition put before the people in Chicago to stop the north side passengers and west side passengers at Clark Street will stand no chance of adoption.

If Mr. Robinson's loop is built, it will have to be built as an entirety and not merely in part; so that it will necessitate much more than 70 per cent of the construction recommended by Mr. Arnold. Whatever plan is adopted we are certainly indebted to Mr. Robinson for an interesting and suggestive discussion of a problem of vital interest to Chicago.

Closure—*Mr. Robinson*: I rather anticipated, that when I said what I had to say, it would stir up some discussion, and I think I have exceeded my best wishes.

It was not my intention that these nine blocks should of necessity be a limiting feature; this group was simply used in this paper as an example, and to suggest how the Inner Circle System could be extended, when the time came to decide on what should be

adopted. If it seemed fit to have it extend north and south in a narrow, oblong form instead of square, then that should be the form; The cross-over tracks, passing from one side of the division loops to the other, were to relieve the congestion at the inner circle. At the same time I appreciate the fact, that this whole plan of mine rather concentrates instead of extends the business center of Chicago, but the present district will always be the neucleus around which this district will grow. I had a little conversation with Mr. Arnold about three years ago on this same subject, and he brought out that same point. Still, I wanted to start a discussion of the subject, and wanted to have the Society take a leading interest in this question as a Society, and that has been, as much as anything else, the object of my paper.

In Mr. Fleming's plan which seems to be one of Mr. Arnold's and the crystalization of the ideas of the others in the discussion of this subject at this meeting, the cars of the North and South sides would come into and pass entirely through the business district to its opposite limits. Then they, or a part of them, would necessarily of course return empty, back, through this congested district, over the opposite track of this loop, which by reason of this arrangement would be the entering track of the lines from the opposite direction, already crowded with its loaded cars.

During the rush hours, the tracks in this district should not be compelled to carry the addition of any empty cars. Loaded cars should be emptied as soon as possible in the congested district and returned as quickly as possible to the loading district. Cars earn nothing running empty, and the more rapid their movement the greater their earning capacity. This is one of the greatest advantages of my plan, namely; that the empty cars are removed from the down town district in the shortest possible time without retarding the operation of any of the loaded cars, either on its own or other lines.

Furthermore, in Mr. Fleming's North and South through line plan, which might be called one of through loops, the track forming these loops would have to carry the combined traffic of both north and south division lines using these loops. Supposing travel to be destined to the southern end, for instance, of this loop. The delay occasioned by this congestion would cause a slower delivery than as if passengers in my plan disembarked from the original line and transferred to comparatively empty cars bound to the same point, but moving more rapidly by reason of less congested tracks. For as cars came in from the North side discharging passengers into the loop district simultaneously with those from the South side, either into the Inner Circle Subway or before it is reached, the cars moving outward again from this loop district would be empty and passengers transferring to these cars would be easily accommodated, without crowding, and arrive at their destination more quickly than as if they had to wait for the total

traffic on the North and South loop to complete its circuit, because of the congestion occasioned by combining the total traffic on the tracks of this single loop.

The present shopping district will always be a neucleus around which travel will center and however much the gentlemen of the street car lines may desire to force people to spread it out, the fact remains that the rush hours will represent simultaneous waves of travel approaching this district from all directions, at the same time during certain hours, and returning at other hours of the day.

In Mr. Arnold's plan are shown three trunk or division lines approaching the downtown district from the north, and three from the South. If these six lines approaching each other from opposite directions and doubling their traffic on the loops through the most congested district, can handle the traffic, surely the seven lines of my plan serving the same areas, with greater speed, hence greater capacity of service, can handle its passengers over its individual terminal loops.

In other words, in Mr. Arnold's plan the attempt is made to deliver each passenger from the North and South sides to his desired destination by means of the street car lines provided this is on the line of this through loop. In my plan I propose to deliver the passenger as nearly to his destination as it is possible to do so and requiring him to finish his trip on foot, to the extent of walking not much over the maximum distance of a block and a half, which does not seem to me to be a very serious hardship even if in doing this he has to use a transfer to reach certain parts of the business area.

As to transfers, people do not dislike them so much if they do not entail a hardship in making them, as for instance waiting on a street corner in the rain. On the contrary, they do rather like a transfer if it can be taken in comfort, under shelter, as in a subway, especially where this transfer savors of the appearance of getting two rides out of street car lines for one fare.

It will be observed in all this discussion by the advocates of Mr. Arnold's plan, that the great West side has been practically ignored. If Chicago was a long neck of land with its most congested business district on a still narrower strip connecting them, the plan could be worked out on Mr. Arnold's lines very satisfactorily. But we have an area lying west of the two branches of the Chicago River that is greater and which presupposes a larger population than the other two divisions of the city.

This population must also have easy, rapid and satisfactory transportation into and out of the business district. These conditions can not be met by driving the tunnels of the West side lines at right angles under the tunnels of the North and South side lines, thus placing the West side tracks on a second level below the street surface. The questions alone of the congestion at the en-

trances and exits of these double decked tunnels, and their great depth would prove fatal to the system. Besides this, there is the serious objection of the threatened stability of the foundations of a majority of the large buildings of the present day, by such deep and wide excavations as those required by these deep subways.

Furthermore the objection of the inelasticity of these deep terminals from the West side can be urged against this plan with more reason, than against the Inner Circle system.

If, however, the lines from the West side enter the business district on the upper level they must terminate at the first north and south line or grade crossings must be introduced. This is a feature that has done more than anything else to nullify the successful operation of the present surface lines, and to which still greater objections can be properly raised if introduced into a subway.

I believe this objectionable feature is of enough importance to warrant us in an earnest endeavor to obliterate it from any system that may be suggested for Chicago.

If the through lines occupy the north and south streets of the eastern part of the business district, in order to permit the west side lines to enter this area as far toward the east as possible, and stop at the first north and south line encountered, a large area of the north-west and south-west portion of the district east of the river is inaccessible except by walking long distances. If, however, the through lines are evenly distributed over this area the west side lines are prevented from entering the down town district as far towards the east side of it, as they should, thus curtailing the effectiveness of the lines from the west to the manifest detriment of the service. In each of these cases the opportunity for transfer from the west to the north sides is very much limited.

Therefore, notwithstanding the preponderance of opinion against my plan in this discussion, I still believe that the ideal and practically successful system of street car terminals in the not far distant future subways of Chicago will embody in a large measure the characteristic features of the Inner Circle System.

ADDENDA.

*Mr. B. J. Arnold* (by letter)—After reading the stenographic report of the discussion of Mr. Robinson's paper by the different speakers I wish to express my appreciation of the able way in which they unanimously defended the through routing principle, and also thank them for the complimentary references to the work involved in my reports to the city.

Owing to the fact, however, that none of those who took part in the discussion, had before them maps of the subway systems proposed by me, I have thought best, in order that a description of these systems may be made a part of the journal of the Society, to submit a discussion of them.

I probably cannot do this in a better or clearer way than by

quoting from portions of my Report of 1902, which relate to the subway question, as the reasons governing my recommendations are there very clearly set forth, and the descriptions accurately given, and I, therefore, quote from Part VI, Chapter I, as follows:

"The problem relating to transportation subways in the business center of the South Side, as submitted to me by your Honorable Body, required the preparation of "preliminary plans for a system of subways which, coupled with the surface system of terminal facilities, or operated independently and without such surface system, will adequately acommodate the traveling public, provide for an increase of traffic in the years to come, relieve the congested condition and create a larger area available for uses by all lines of business; these plans to show a feasible disposition of all existing underground improvements, so disposed of as to permit of easy access for future repairs, renewals and reinforcements without disturbing the street surface."

The treatment of these various divisions of the subway matter is shown on Maps Nos. 5 and 11 and Plates numbered 1 to 9 inclusive.

As previously stated, I have arrived at the conclusion that it is impracticable to devise a system of underground transportation for the central down-town district, which will forever fully supply adequate terminal facilities for the very large traffic entering that district, and that any satisfactory system of terminals capable of meeting the future demands that will be required within the limited area available, must include a combination of surface and subway tracks.

### ULTIMATE OBJECTS.

In the development of the subway plans submitted herewith there have been kept in mind the following principal objects:

First.—The ultimate unification of all street railway facilities within the city limits under a single operating management.

Second.—The proper location of the subway lines and the construction of a track system which will provide for the operation of cars under any of the following plans:

(A) Between the various divisions of the city through the business district.

(B) Divisional operation of the cars only; using the subway system as a loop terminal.

(C) Plans (A) and (B) in combination.

Third.—To build the subway as close to the surface of the street as possible; reducing the distance from station platforms to the level of the street to a minimum.

Fourth.—The arrangement of a subway system to provide for the maximum efficiency with a minimum length of underground tracks.

Fifth.—The disposition of all underground utilities in such a

manner that they will be easily accessible without disturbing the surface of the street, and without any direct connection with the transportation subway.

The question of keeping as much of the subway as possible close to the surface of the street being considered of prime importance, both in respect to greater convenience when completed, and the probable large saving in the cost of construction, it at once became apparent that in meeting the requirements of the committee in respect to the disposition of existing underground improvements the subject must be treated on the broad grounds that the entire width of a street between building lines is set apart for public uses and that wherever transportation subways are to be constructed in a street the space beneath the sidewalks must of necessity be used for the purpose for which it was originally set apart, i. e., the disposition of public utilities.

It may be said with propriety that all pipes and conduits in streets, especially those in the streets of business districts, should be placed in properly constructed galleries, to avoid the incessant disturbance of the street surface which existing methods necessarily entail. Wherever practicable these galleries should occupy the space beneath the sidewalk, and in preparing the drawings for subways this plan of disposing of the underground improvements has been followed.

## SUBWAY ROUTES.

The location of subways shown on Map No. 11, hereinafter referred to as Subway Plan No. 1, is suggested as the most feasible plan for accomplishing the foregoing objects without disturbing the existing low level improvements, which have been avoided by slightly increasing the grades of some of the tunnel entrances. The arrangement of the subways shown in this plan is believed to provide the greatest possible elasticity in respect to operation. It is in full harmony with all the suggestions herein made for re-routing cars. Adhering to the general plan of recognizing the north and south lines as the "trunk lines," and to arrange the track system in the subway and on the surface of the streets in a manner so as to practically eliminate grade crossings, it is proposed to take such north and south traffic as may hereafter be deemed advisable into and through the business district in the subway, except that portion of the traffic from the South Division of the city which may be routed over tracks in the southerly portion of the West Division, via the West Division surface and subway terminals and such north and south traffic as may be thought best to retain upon the surface of the streets. Under this plan the north and south subways would be located in Wabash avenue, State street, Dearborn street, Clark street and partially in La Salle street, and would extend from Fourteenth street on the south to Indiana street on the north.

In Wabash avenue from Fourteenth street to Hubbard place the subway would be double tracked. From Hubbard place to South Water street a single track subway for north-bound traffic would be constructed under the easterly roadway and sidewalk. The entire structure of the single track subway in Wabash avenue would be east of and removed several feet from the substructure of the Elevated Railroad in the same street (see Plates 7 and 9), thence turning west in South Water street as a single track structure to State street, where the structure will again become a double track subway; thence continuing westwardly in South Water street to Dearborn street; thence north in Dearborn street, passing under the river in a new double track tunnel and reaching the surface again at or near Indiana street. This subway could be carried if it should be deemed advisable, under the river at or near Cass street. The southbound Wabash avenue traffic between South Water street and Hubbard court would be taken through the subway on the easterly track in State street.

The subway in State street would be a double track structure from Fourteenth street northwardly to Polk street. From Polk street to Hubbard court this subway would be a single track structure, in which the north-bound traffic would cross to the westerly subway track in State street. From Hubbard court to Lake street the subway in State street would be a double track structure. At Lake street the north-bound State street track would curve into Lake street and run westwardly in a single track subway to Dearborn street, where the structure would again become double tracked and continue westwardly in Lake street to Clark street; thence north in Clark street and under the river through a new double track tunnel, coming to the surface again at or near Indiana street. The south-bound State street traffic between Lake street and Polk street would be carried in Dearborn street and via a single track subway in Polk street to a connection with the south-bound track in State street south of Polk street.

The subway in Dearborn street from Polk street to Randolph street would be a double track structure. The easterly track would be designed to carry south-bound State street traffic and the westerly track north-bound Clark street traffic. At Randolph street the westerly Dearborn street track would turn west into Randolph street in a single track subway to Clark street, where the structure would become double tracked, continuing westwardly in Randolph street to LaSalle street; thence north in LaSalle street and under the river through the LaSalle street tunnel, the tracks coming to the surface again at or near Indiana street.

The Clark street subway would be a double track structure from Fourteenth street to Polk street. From Polk street to Jackson boulevard the south bound Clark street track would be in a single track subway which would cross to the east side of Clark street at Harrison street. From Jackson boulevard to Washington

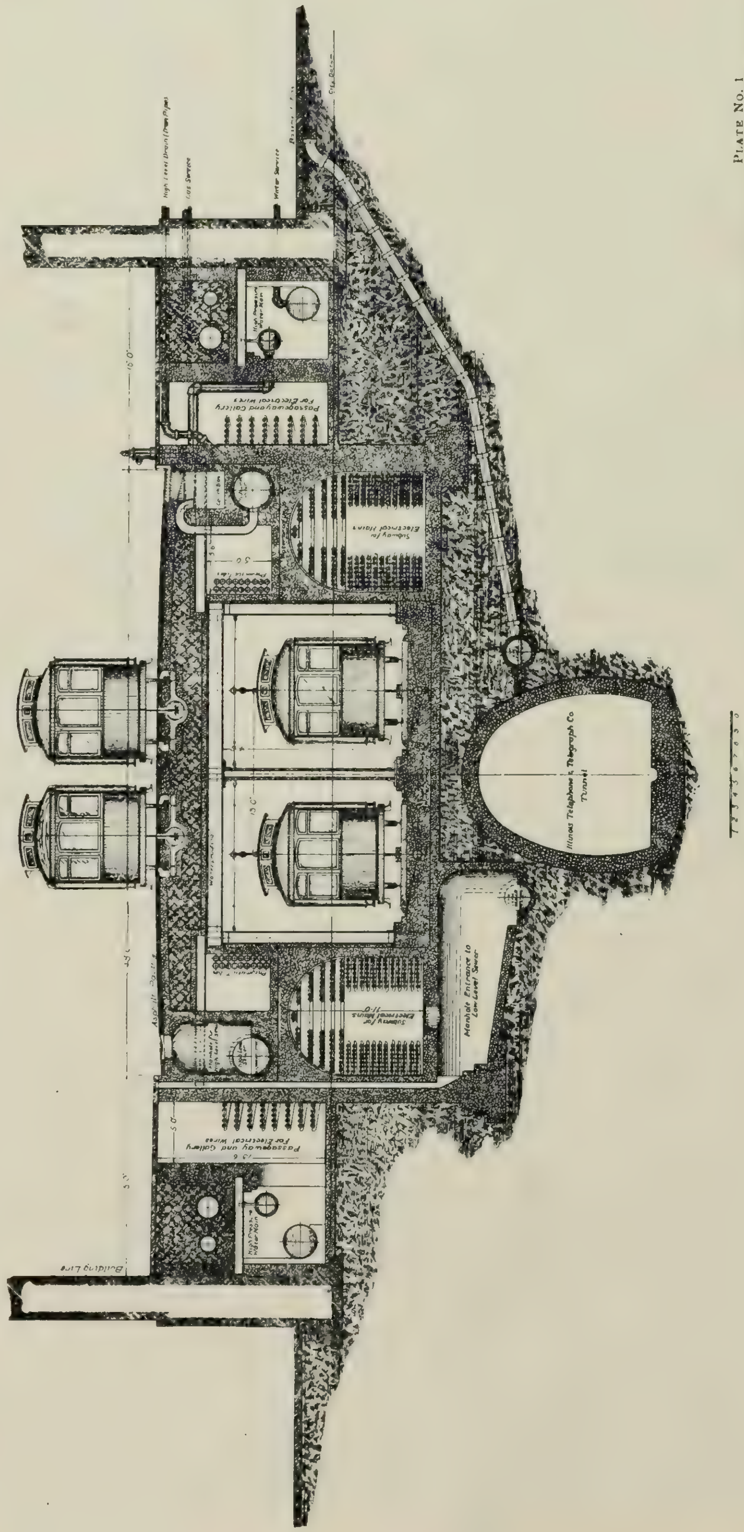



PLATE No. 1
TYPICAL CROSS-SECTION BETWEEN STATIONS
FOR
PROPOSED STREET RAILWAY SUBWAY
OVER LARGE TUNNEL OF ILLINOIS TELEPHONE & TELEGRAPH CO
ON STREET 80 FEET WIDE
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902

street the Clark street structure would be double tracked, the westerly track forming the easterly track of the two loop subways connecting with the Washington street and the Van Buren street tunnels for West Division traffic. The easterly track in Clark street would continue northwardly in Clark street to Randolph street, where it would connect with the double-track structure in Randolph street, leading to the LaSalle street tunnel. The westerly Clark street track would connect at Washington street with the single-track structure leading to the Washington street tunnel. The north-bound track in Clark street would turn east in Polk street as a single-track structure and connect with the easterly track in Dearborn street.

At Monroe street double track cross connections with suitable curves would be made between the Wabash avenue track and the easterly track in State street, between the westerly track in State street and the easterly track in Dearborn street, and between the westerly track in Dearborn street and the easterly track in Clark street for the purpose of supplying the necessary loop connections for operating the cars of either the North Division or the South Division into the business district and return without reference to through traffic.

The subway in Washington street would be a double tracked structure from Clinton to Market streets passing under the river through a reconstructed Washington street tunnel. The east-bound track would turn south in Market street in a single track subway to Monroe street; thence east in Monroe street to Clark street to a connection with the westerly track in Clark street. The west-bound track would be a single track subway in Washington street from Market street to Clark street, where it would connect with the westerly Clark street track, completing the subway loop for traffic through the Washington street tunnel.

The subway connecting with the West Chicago Street Railroad tunnel near Van Buren street would be a double track structure in Market street from a connection with the river tunnel to Jackson boulevard. The east-bound track would turn east in Jackson boulevard as a single track structure to a connection with the westerly track in Clark street. The west-bound track would continue in Market street to Adams street as a single track structure; thence in Adams street to a connection with the westerly track in Clark street, completing the loop for West Division traffic passing through the West Chicago street railroad tunnel. Curved connections would be provided between the two West Division subway loops and the north and south subways in Clark street to provide for through traffic via the subways between the West Division and the North and South Divisions of the city.

The length of subways to be constructed along the routes described, exclusive of the tunnels under the river, would be 20,-

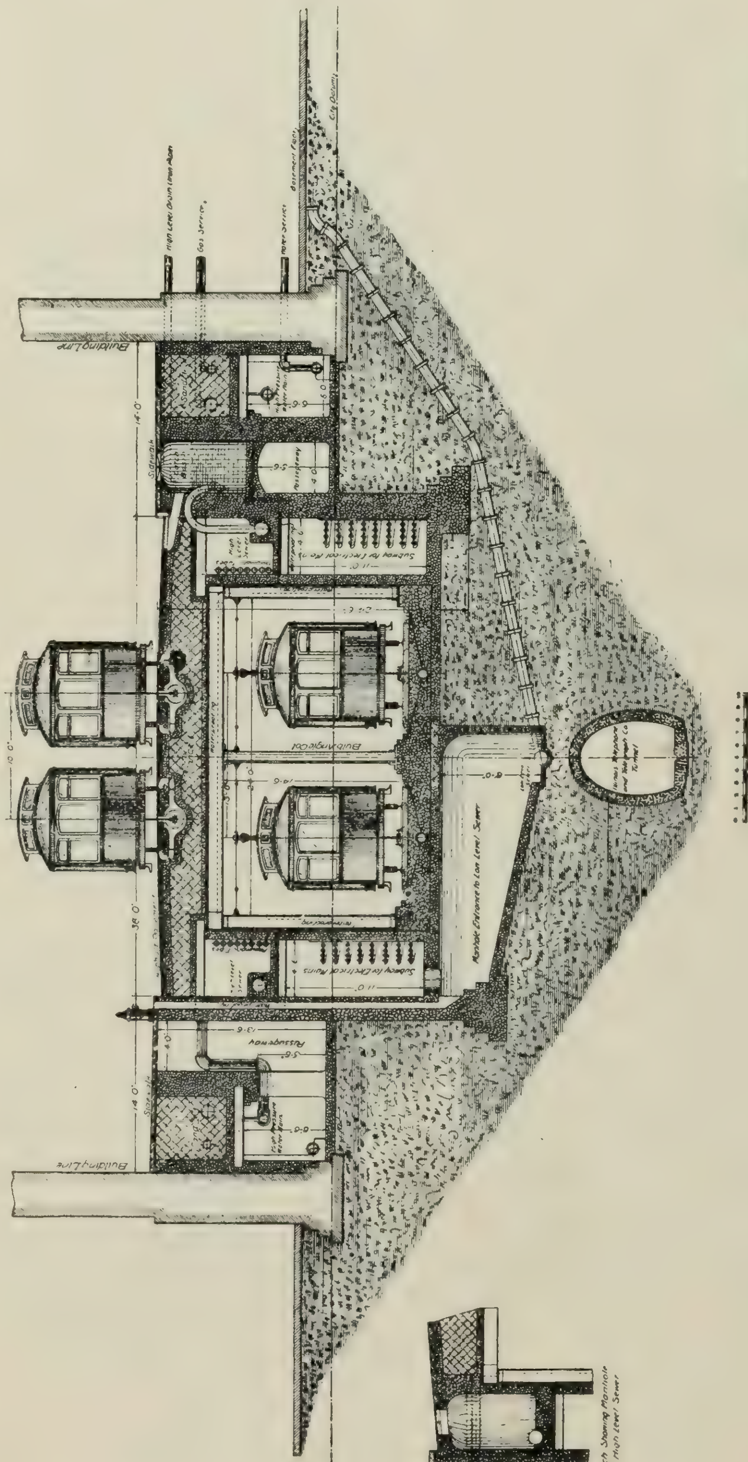
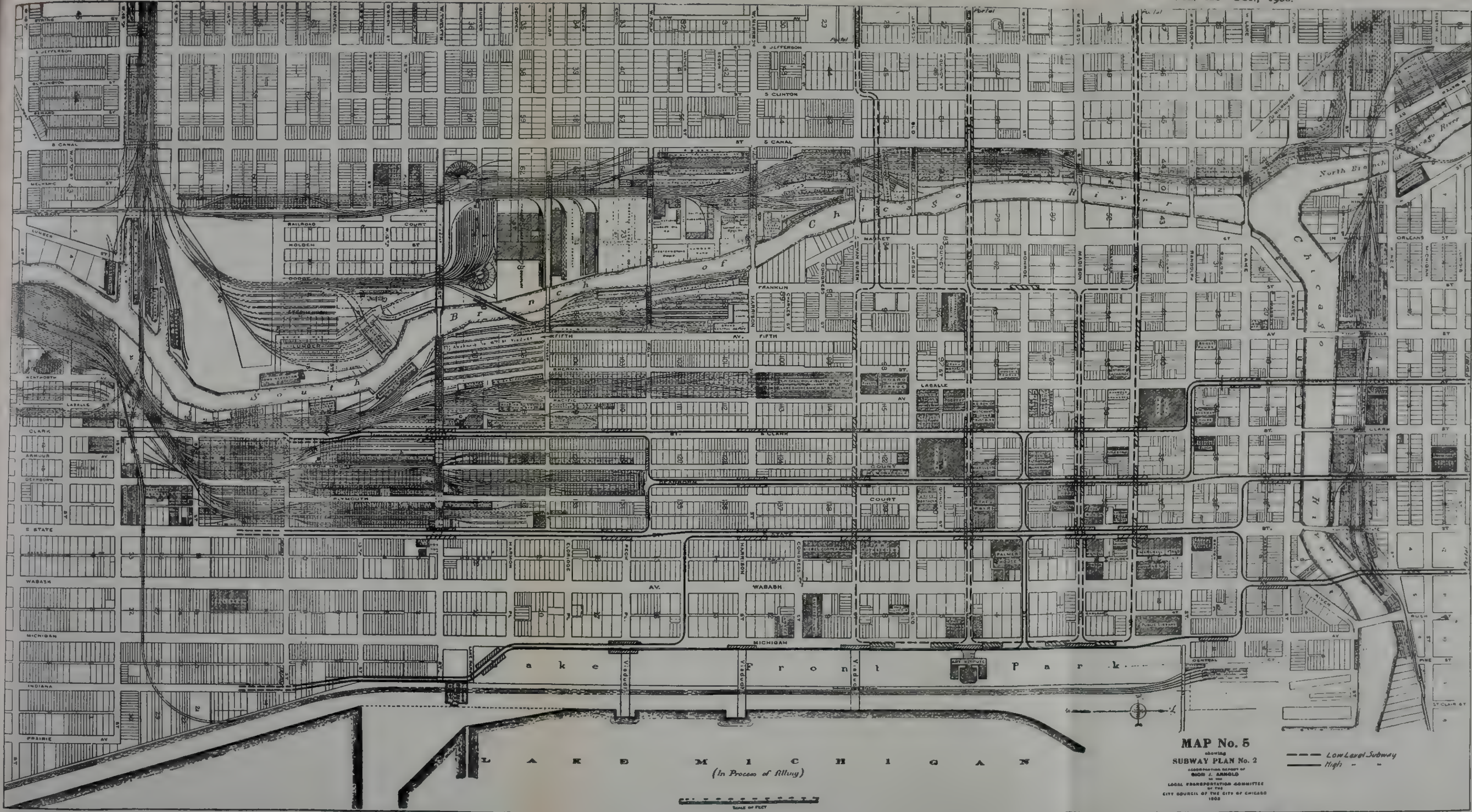
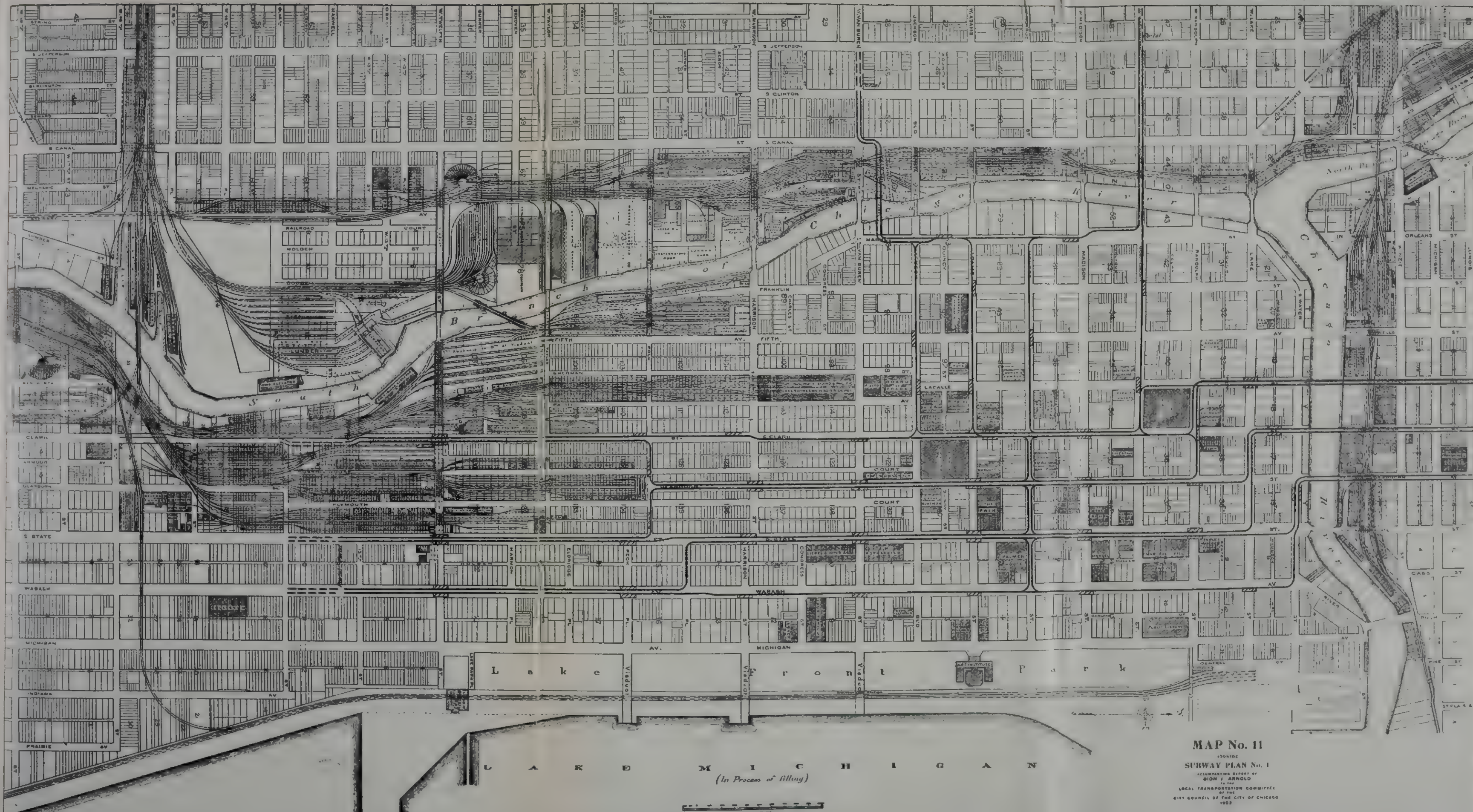


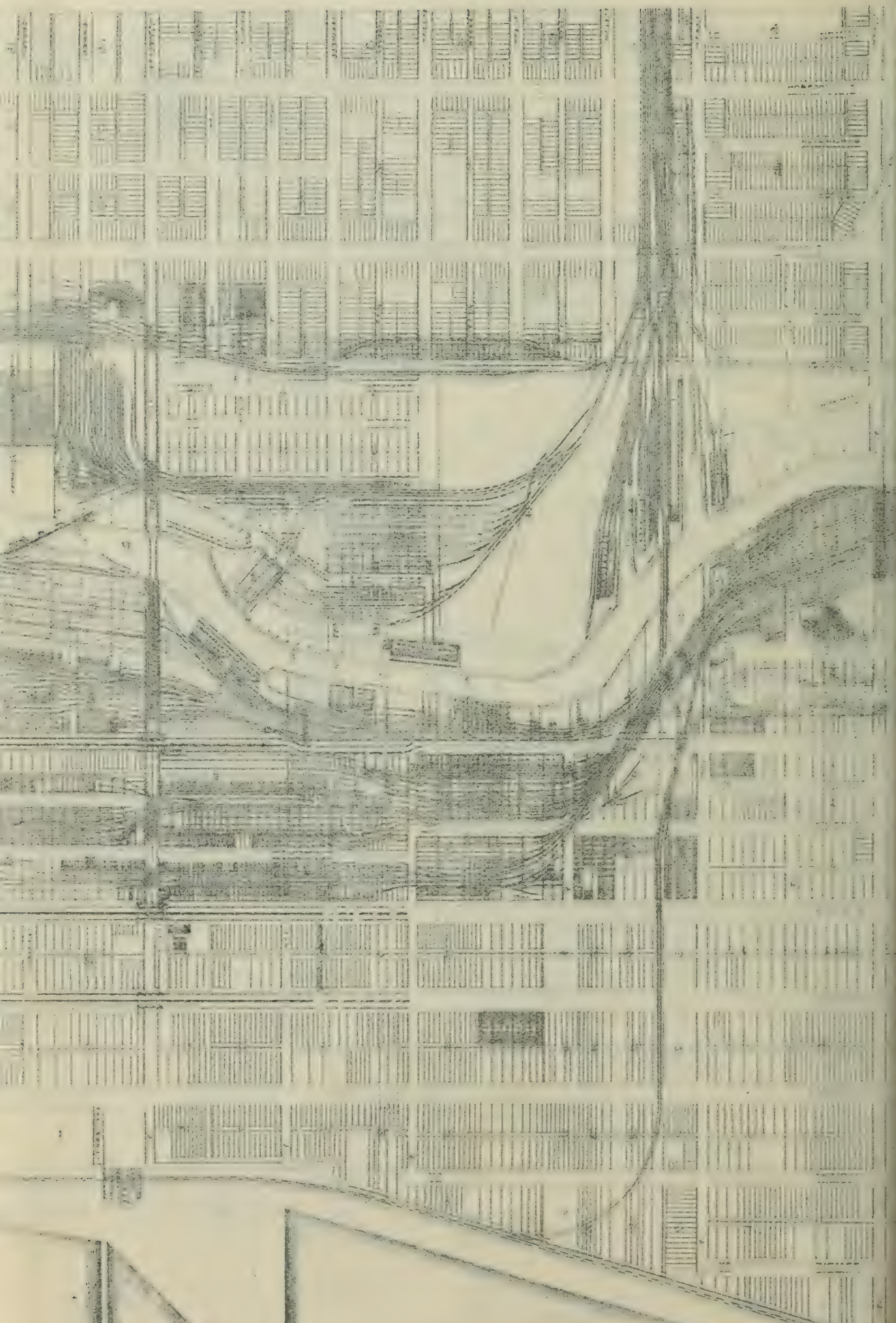
PLATE No. 2.
TYPICAL CROSS-SECTION BETWEEN STATIONS
FOR
PROPOSED STREET RAILWAY SUBWAY
OVER SMALL TUNNEL OF ILLINOIS TELEPHONE & TELEGRAPH CO
ON STREET 66 FT. WIDE
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902




Subway Plan No. 2.




Subway Plan No. 1.



825 lineal feet of double track structure and 20,000 lineal feet of single track structure.

The proposed subway construction is shown in the drawings accompanying this report. Plates 1 and 2 show typical cross sections of a double track subway in 80 and 66 foot streets. The cross sections shown on Plate No. 1 represents the subway located above the large tunnel of the Illinois Telephone & Telegraph Company, and that on Plate No. 2 represents the subway above the small tunnel of the same company. Plate No. 3 shows a typical cross-section of a double track subway at a station. The normal section of the subway proper would be rectangular, with the tracks side by side, and consist of transverse bents of steel columns and roof beams, which would carry side walls and a roof of concrete arches and rest on a concrete floor. The side columns and the roof beams would be rolled I-beam sections and the central columns would be built up of angles and plates rivited together. The entire four sides of the section would be protected from seepage by a layer of water-proofing embedded in the floor, walls and roof.

As indicated on Plates Nos. 4 and 5, it is proposed to place the station entrance and exit stairways at the outer edge of the sidewalk space, the stairways leading down to a corridor located just inside the curb wall line, and opening onto the station platform, which would be 13 feet in width and about 150 feet in length. Wherever possible the stations should be located at street intersections with the platforms extending an equal distance each way from the center of the street crossing the line of the subway, and with a stairway leading down to the station from the subway street on each side of the intersecting street, as shown on Plate No. 4.

The walls and ceilings of all passageways leading to the station platforms and the walls and ceilings of the station should be finished in white glazed terra cotta or other equally attractive material.

In regard to the adoption of a proper cross-section for the subways: Since the principal function of the sub-surface tracks will be to serve as terminals for the traffic coming from the various street railways centering in the business district, the impracticability of considering the use of a special type of rolling stock for the purpose of contracting the area of the subways is obvious. With the development of mechanical propulsion of street cars there has been a steady increase in the size and weight of cars, and at the present time there are in service on some of the lines in this city cars which are more than eleven feet in height, exclusive of trolley stands, eight feet six inches in width, forty-seven feet in length and weighing fifty thousand pounds, exclusively of the live load. The cross-section of the subways has been fixed to provide for the operation of these large cars and the necessary clearance to

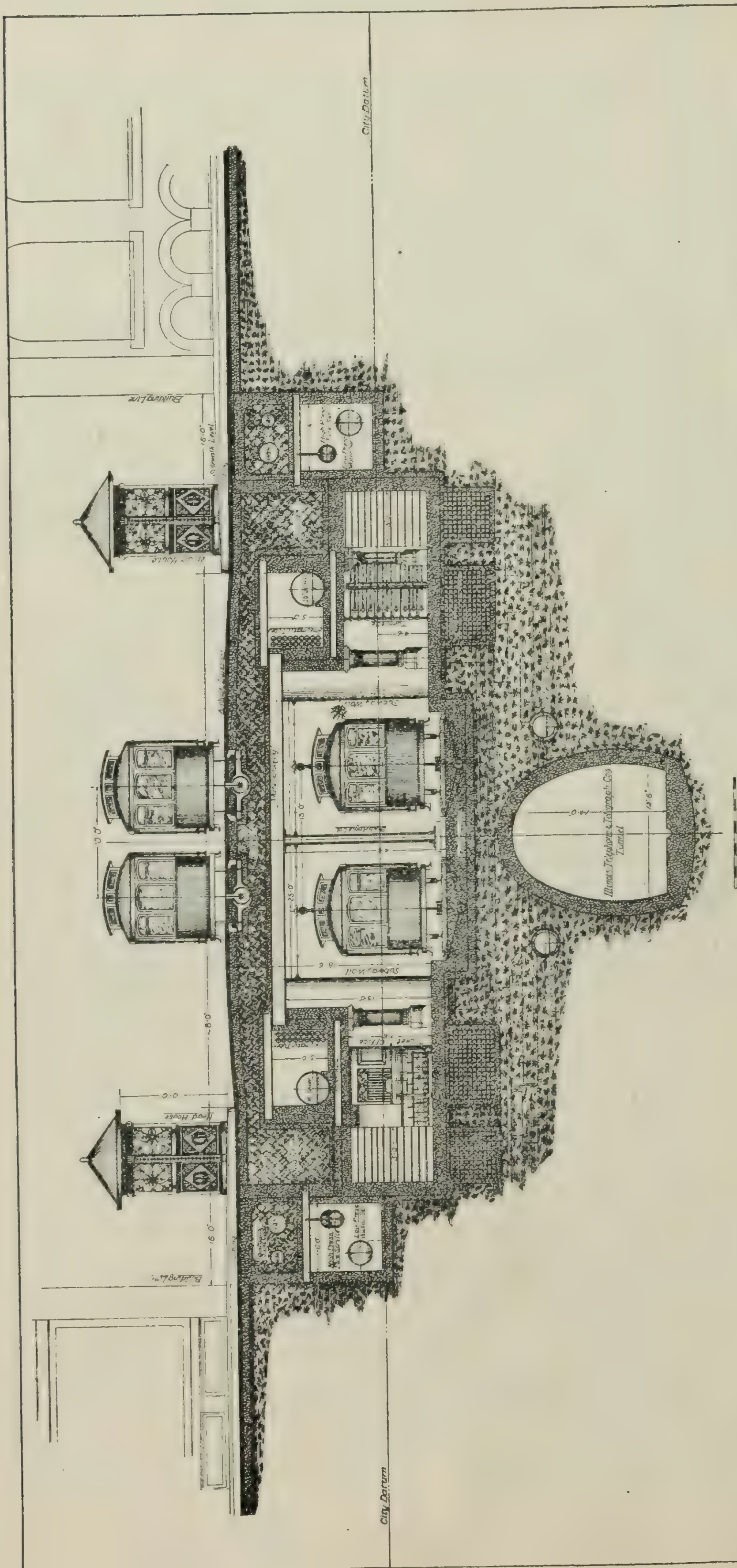



PLATE No. 3
TYPICAL CROSS-SECTION THROUGH STATION
FOR
PROPOSED STREET RAILWAY SUBWAY
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902

insure safety to passengers and also to the force of employes which would be stationed in the subways for the purpose of inspection and repairs to the tracks.

The resulting interior dimensions of the subway would be as follows: Clear height above track rail, 14 feet 6 inches; clear width between side walls, 25 feet; clearance between the wall and the car, 1 foot 8½ inches; clearance between the central columns and the car, 1 foot 8½ inches; total distance between passing cars, 4 feet 3 inches.

The central space between the tracks would afford employes ample opportunity to seek shelter from passing trains. And where a line changed its direction the curves would be so laid that safe clearances between passing cars and between the cars and subway walls and columns would be maintained.

When detailed plans of a subway system are finally made they should provide for the operation of the longest and heaviest standard suburban cars that the curvature conditions will permit."

* * * * * * * * * * * * *

SUBWAY PLAN NO. 2.

"The subway system above described has been carefully designed, and it is believed that it will best fulfill the conditions necessary for the successful operation of a combined surface and subway railway system which is practicable without interfering with existing low level improvements.

Its chief advantage, from an operating standpoint, is that it keeps all through traffic, both north and south, and west to south, and west to north, off the surface of the streets, and will permit rapid running time for such traffic to be made through the business district of the city.

Plan No. 1 as outlined does not meet all the conditions for a complete and satisfactory solution of the transportation problem, even if used in connection with any system of surface terminals that can be devised, for the following reasons:

First—if used in connection with Surface System No. 1, as shown on Map 10, which is the best loop system I have been able to devise to most effectually utilize the business district for terminals without using grade crossings, all north and south cars would be compelled to use the subways, and almost all of the West Side cars would be brought into the business district on the surface.

From the viewpoint of those who consider that part of the traffic from all parts of the city should be conducted on the surface of the streets this plan would not be a satisfactory solution of the problem, but it is submitted as one plan complying with the conditions of my commission "to eliminate grade crossings."

Second—While some of the objections just cited would be removed by using this subway system in combination with either of the surface plans shown on Maps 2 or 3, the use of such a com-

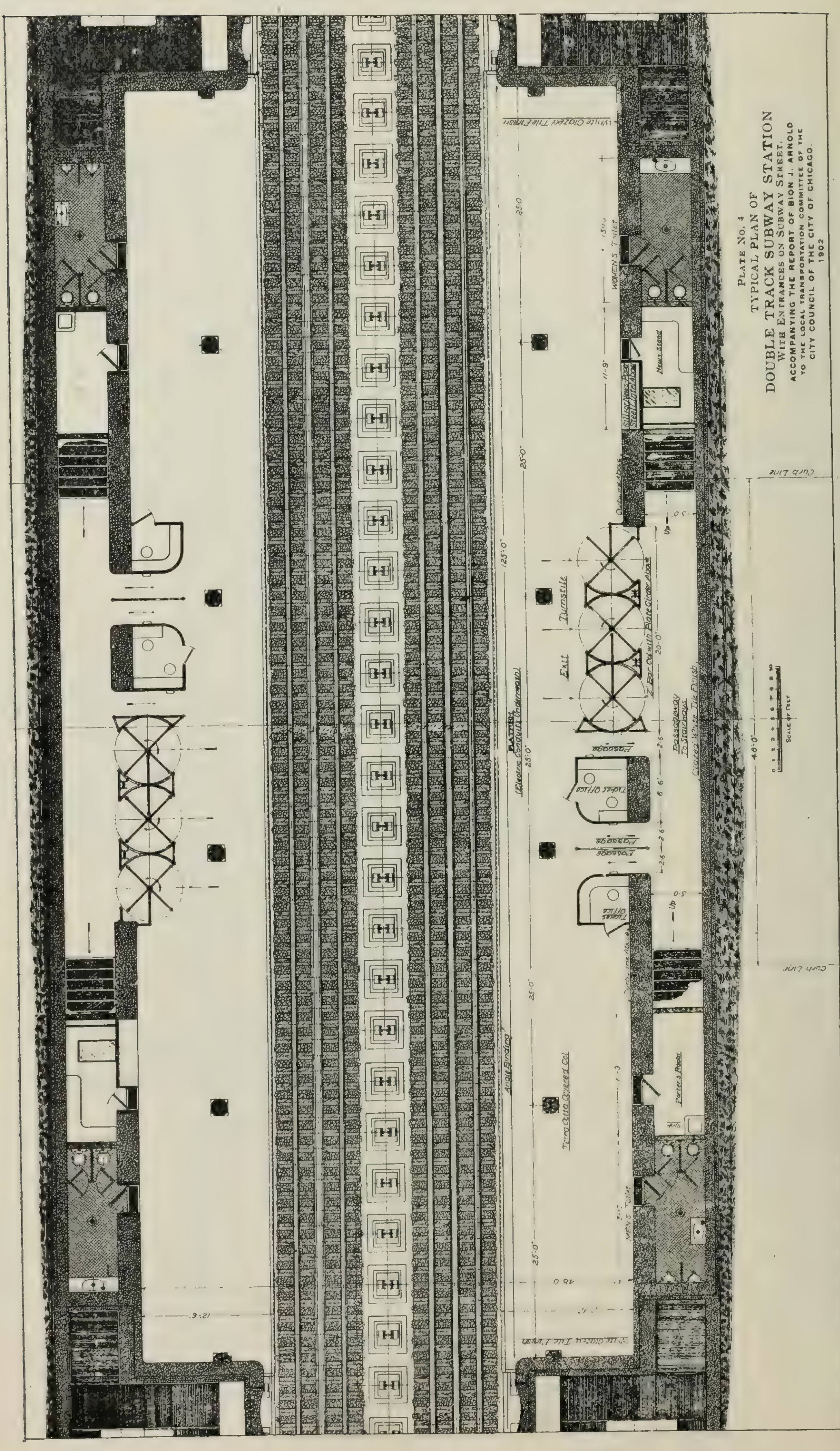



PLATE No. 4
TYPICAL PLAN OF
DOUBLE TRACK SUBWAY STATION
WITH ENTRANCES ON SUBWAY STREET.
ACCOMPANYING THE REPORT OF BION J. ARNOLD
TO THE LOCAL TRANSPORTATION COMMITTEE OF THE
CITY COUNCIL OF THE CITY OF CHICAGO.
1902

bined system would still compel all passengers arriving on the West Side subway cars to transfer to surface cars if they desired to ride farther east than Clark street.

This objection could be, in a degree, overcome by moving the entire system of subways east one block, thus locating the subway shown under Wabash avenue, under Michigan avenue, and permitting the West Side subway loops to come as far east as Dearborn street.

Third—The use of the system in combination with any surface system permits and creates the best possible condition for the improper use of transfers in the business district by compelling all passengers desiring to go west from the north and south subways to transfer to surface cars, unless they chance to be passing through the Clark street subway.

In order to overcome the above objections, and submit for your consideration a complete and ideal solution of the transportation problem, and to absolutely solve the question submitted to me by you, and stated on Page 133, Subway Plan No. 2 has been devised, which is shown on Map No. 5.

All of the advantages of through routes, in all directions, of Plan No. 1 are retained, its objections are fully overcome, and its use makes it possible for the city to demand from the railway companies a universal transfer system without injustice to them. It, however, is submitted as an ideal solution of the situation with the full understanding of the difficulties which will be encountered in its construction, and in full recognition of the fact that the cost of a subway system built under this plan will be somewhat in excess of that required by the previous plan, and that more difficulties will be found than would be encountered in the adoption of Plan No. 1.

This plan retains the same north and south trunk line system of tunnels as shown in Plan No. 1, except that the line on Wabash avenue is moved over to Michigan avenue, and run underneath the edge of Lake Front Park, thus enabling this line to be entered at the south by the present Indiana avenue line, provided a suitable extension of the Indiana avenue line from Eighteenth street north is made to connect with the subway, as shown on Map No. 5.

It will be noticed that the subway under Michigan avenue would pass under the river at Cass street, which arrangement could also be adopted for Plan No. 1 if it should ultimately be found advisable.

This arrangement would eliminate the difficulties which would be encountered by passing under the bridge on Dearborn street.

If for any reason it were found desirable this line could be placed under Wabash avenue instead of Michigan avenue, as in Plan No. 1.

In order to get the West Side lines through to Michigan avenue and ultimately farther east under the Lake Front Park should

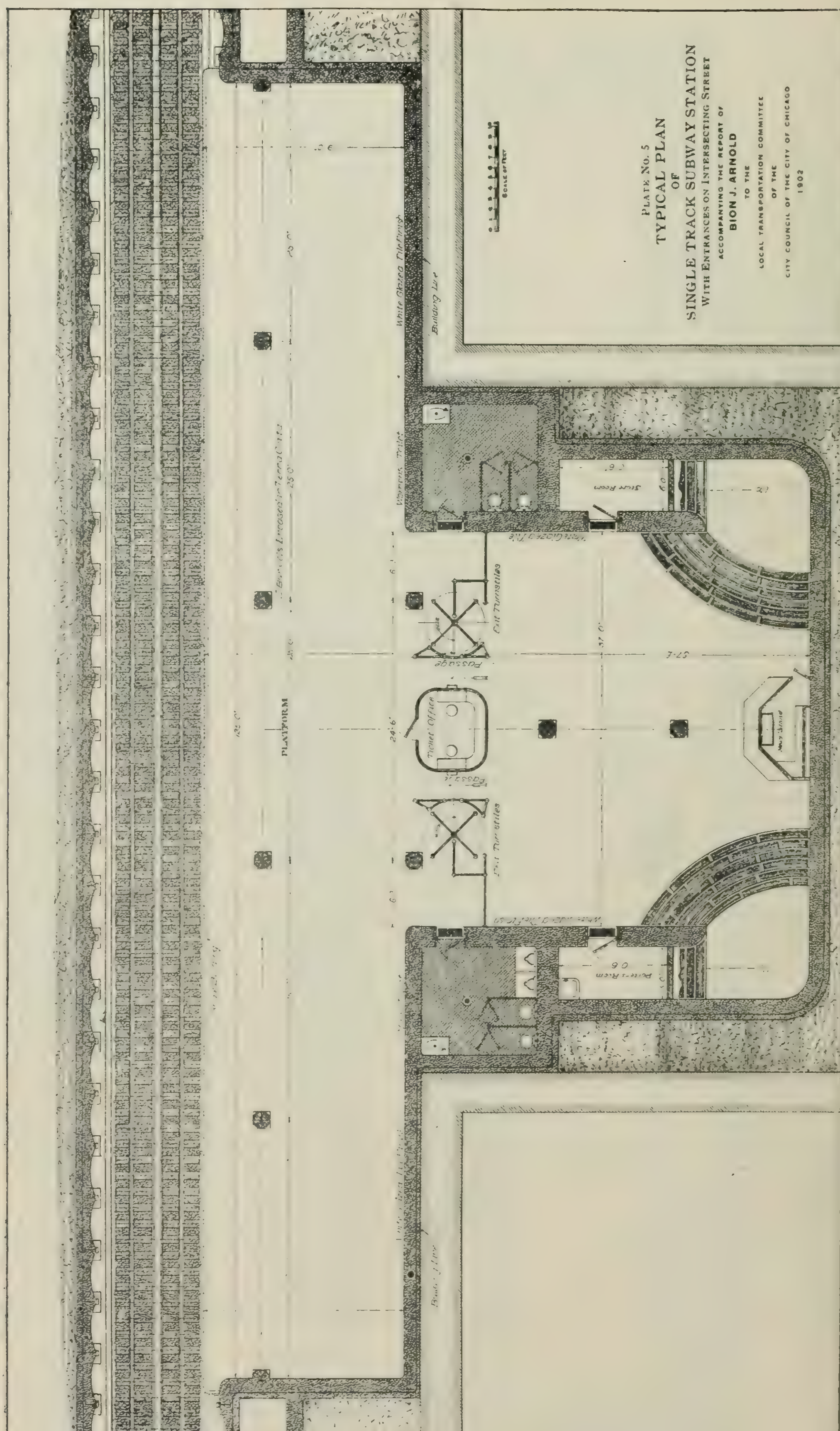


PLATE NO. 5
TYPICAL PLAN
OF
SINGLE TRACK SUBWAY STATION
WITH ENTRANCES ON INTERSECTING STREET
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902
PLATFORM
Ticket Office
Passage
Exit Turnstiles
Building Line

future extension of the park make this desirable, or if it should be thought best to connect the various passenger and freight depots of the steam railroads, a series of low level loops could be provided. These loops would extend eastward from the river at as high a level as practicable to keep underneath the north and south subways, and where they intersected the streets occupied by north and south subways double-decked stations could be provided, as shown in Plate 9. In this station, as designed, all of the business would be done on the first floor below the street surface, and the lower section of the station would consist only of platforms from which passengers would board the trains. From the lower level platform to the platform of the upper subway would be provided stairs at one end, and, if found advisable, elevators or escalators at the other end, thus making the ascent easy for those who desired to use them.

By the construction of the three or more north and south subways and the three or more low level east and west loops the entire street car traffic of the business center of Chicago could be kept below the surface for some years to come, except the traffic which would be handled by the surface distributing loop extending between the depots, thus eliminating the necessity of constructing a large part of the underground conduit electric construction at the present time, and if some independent unit system of operation should be adopted for this surface distributing system, the necessity of underground conduit construction in Chicago would be entirely eliminated until such time as it became necessary to put additional surface tracks on the streets.

It will thus be seen that the business center of the city would, if this plan were adopted, be underlaid with a series of subway tracks intersecting each other at right angles, and at a sufficient number of points to enable passengers to travel from almost any point in the business district to almost any other point with the least inconvenience, and at the same time make it impossible for passengers to improperly use transfers, for the reason that in order to get on a car the passenger must pay cash fare and pass through a subway entrance, and when transferring from any high level subway car to any other high level subway car, or from any high level subway car to any low level subway car, he cannot come to the surface to dispose of his transfer, and must of necessity take some car and use his transfer himself, for if he comes to the surface it is of no value, for the reason that no one can enter the subway on a transfer. It might be argued that this does not prohibit the misuse of transfers for the reason that some one could meet the passenger in the subway and receive and use his transfer, but this person cannot enter the subway without having paid a cash fare, consequently this argument would not prevail.

In time, after the capacity of all possible subway terminals had been reached, it would become necessary to construct surface tracks

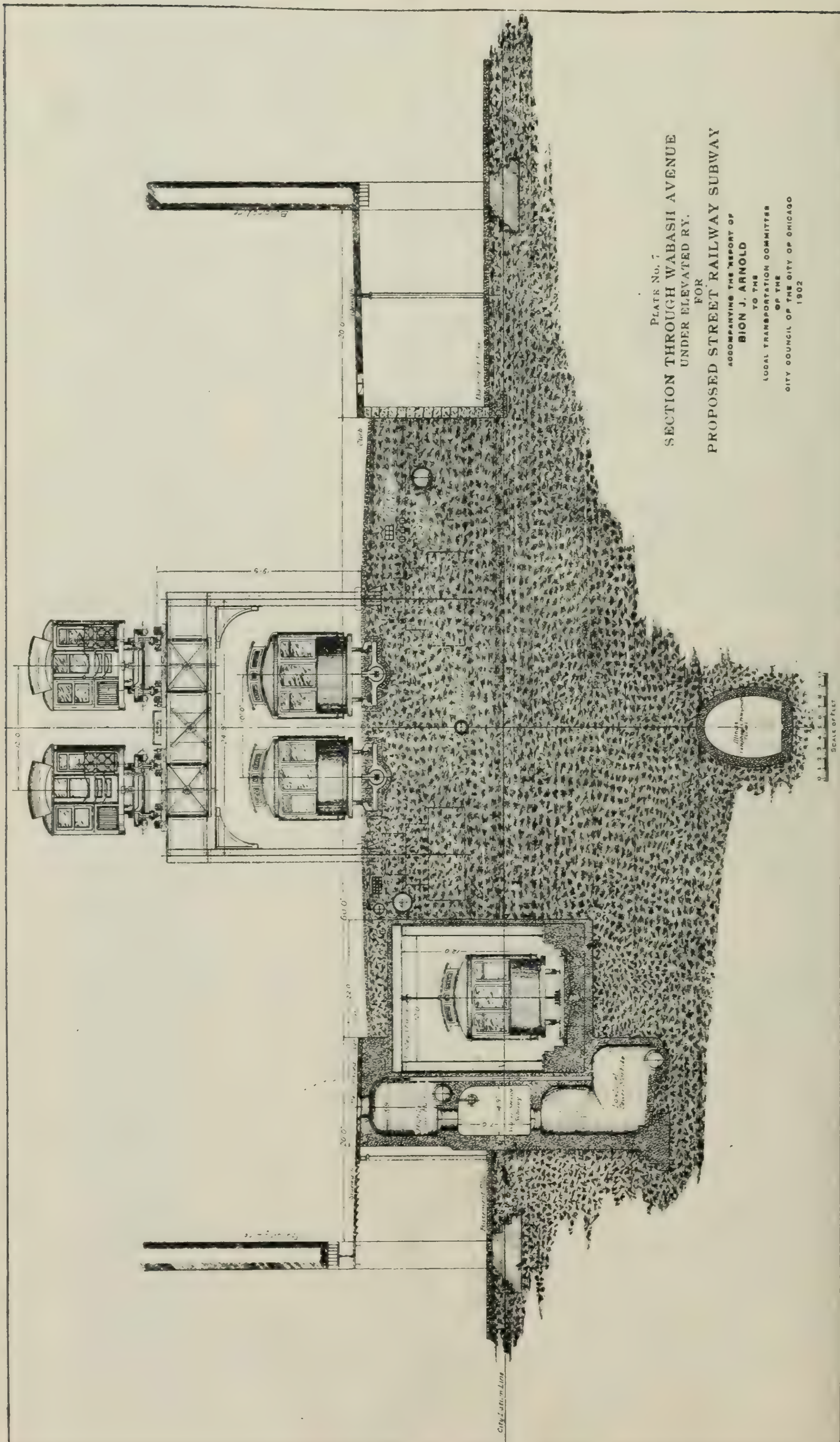


PLATE NO. 7
SECTION THROUGH WABASH AVENUE
UNDER ELEVATED RY.
FOR
PROPOSED STREET RAILWAY SUBWAY
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902
SCALE OF FEET
City Lot Line
Curb

in accordance with Plans 2 or 3, shown on Maps 2 and 3, or some other plan, which would involve the delivering of a large number of passengers in the down-town district from the surface lines. These passengers should not be permitted to transfer from one surface line to another, or from a surface line to the subway within the subway district, for the reason that if they desire to pass through from one part of the city to another they should be required to take a subway car, or if they chanced to be upon a car which did not pass through the subway they should transfer to subway cars at points outside the subway district, thus eleminating to the greatest degree the possibility of the improper use of transfers.

OBJECTIONS TO SUBWAY PLAN NUMBER 2.

It is believed that the merits of this system have been fully set forth, and the objections to it should also be recognized in the consideration of the transportation problem. The chief objections that can be made to it are:

First—Its relative cost as compared with Plan No. 1.

Second—The passengers in the low level subways would be about 40 feet below the surface of the street, thus necessitating the use of elevators between low level and high level subways at station points, a distance of about 20 feet.

Third—The engineering difficulties and risks that would be encountered in its construction.

Fourth—The fact that it would interfere, and to a large extent destroy, existing and contemplated low level improvements.

The importance of the first objection can be analyzed by comparing the estimated cost of this plan, as shown in Cost Estimate No. 3, Page 236, with the cost of Plan No. 1, as shown in Cost Estimate No. 2, Page 233.*

The second objection can only be answered by the individual opinion of those who might ride upon the system. In my judgment it is not serious.

The third objection, or the engineering difficulties and business risks to be assumed during the construction of such a low level street car subway, is difficult, and would require the exercising of great skill and care during construction, but can be overcome and is in my judgment comparatively small when compared with the advantages to be gained by the adoption of such a system.

The fourth objection is, in my judgment, difficult to overcome, as the changes that would necessarily have to be made in the existing and contemplated low level improvements of the Illinois Telephone and Telegraph Company to make room for the low level subway herein contemplated would probably involve heavy expenditure of money, and the relative importance of the advantages

---

*Estimated cost of Plan No. 1, $16,000,000.
Estimated cost of Plan No. 2, $20,000,000.

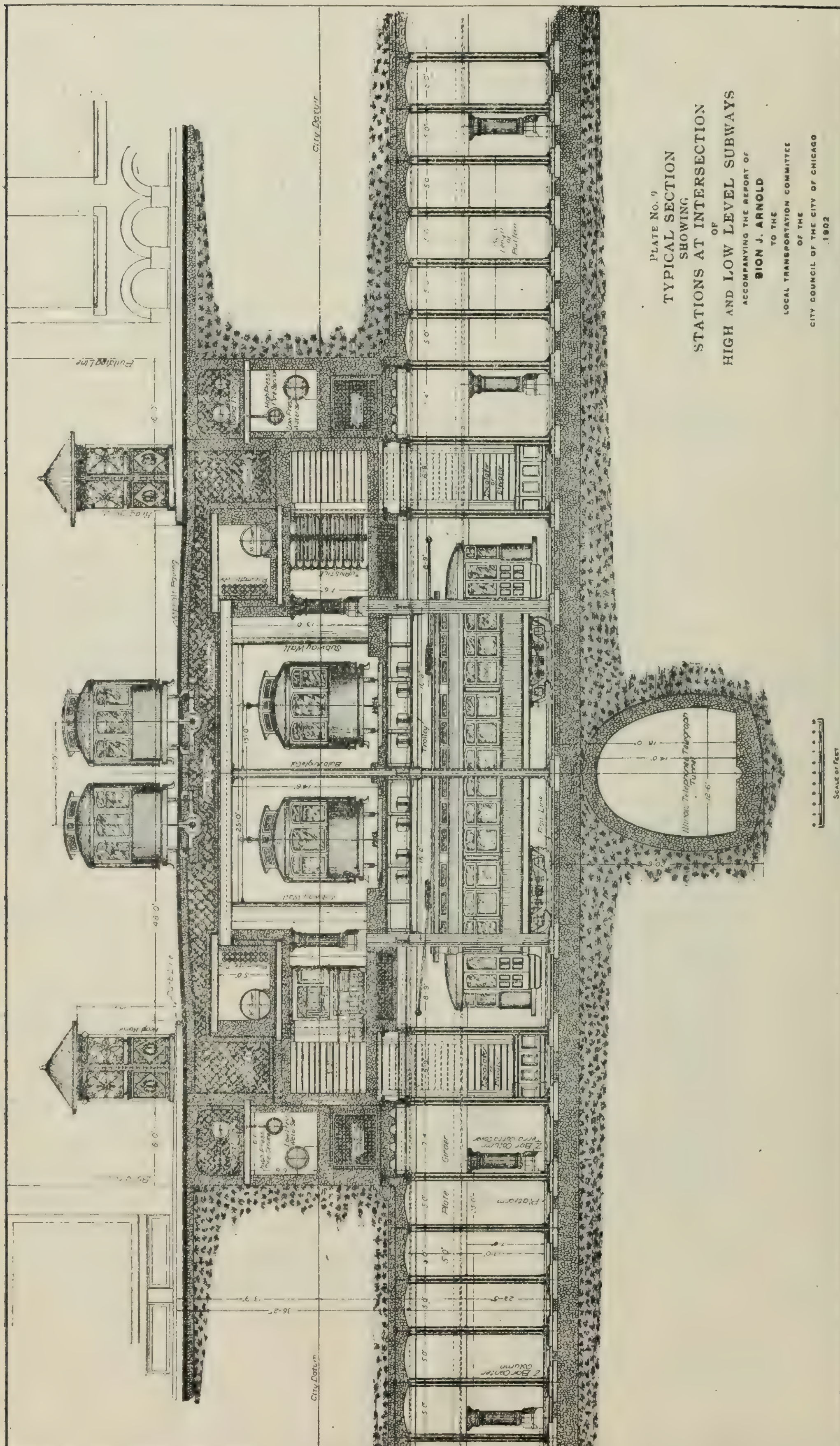


PLATE No. 9
TYPICAL SECTION
SHOWING
STATIONS AT INTERSECTION
OF
HIGH AND LOW LEVEL SUBWAYS
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
TO THE
LOCAL TRANSPORTATION COMMITTEE
OF THE
CITY COUNCIL OF THE CITY OF CHICAGO
1902

to be gained by the high and low level system of street car subways as compared with the advantages to be gained by the business interests of Chicago from the installation and operation of the existing and contemplated low level improvements of the Illinois Telephone and Telegraph Company, the ultimate function of which, in additions to the use for telephone and telegraph purposes, I understand to be the carrying and delivering of freight and packages from all railway terminals to all business houses in the city, should be well considered by your Committee and by all those whose duty it may be to ultimately decide this question. If some amicable arrangement could be made between the interests which may construct the proposed high and low level street car subway system, provided it is decided to construct it, and the interests controlling the Illinois Telephone and Telegraph Company, whereby the tunnels of the latter company could be utilized as the low level subways for the street car system, it would be one way of solving this difficulty, or if an arrangement could be made whereby the low level street car subways and the tunnels of the Illinois Telephone and Telegraph Company could be constructed jointly, and at the same time, it would to a large extent, relieve the difficulties to be encountered."

Since the report was written the Illinois Tunnel Company (successor to the Illinois Telephone & Telegraph Company), has been granted an ordinance authorizing it to carry freight in its subways. This ordinance, however, contains a provision which compels the Company to keep the tops of its subways in the downtown district sufficiently low to allow the construction of Subway Plan No. 2, so that the chief objection, above pointed out, no longer exists to this plan.

A study of Plan No. 2 shown on Map No. 5, will show that it has the same number of loops, viz: three, from each division of the city, that Mr. Robinson's plan has, although those from the north and south sides are intended to be used only as supplementary to the through routing system.

Furthermore both these loop systems terminate at Monroe street and the loops from the West Side at Michigan avenue, thus delivering the North Side passengers farther south, the South Side passengers farther north, and the West Side passengers farther east than is possible with Mr. Robinson's system, without transferring, and at the same time providing the business center with a system of distribution which will enable a passenger to get from almost any point to almost any other point with but one transfer and in many instances without transferring at all.

## ABSTRACT OF THE MINUTES OF THE SOCIETY.

*MINUTES OF THE REGULAR MEETING, September 5, 1906.*

A regular meeting of the Society (No. 580) was held Wednesday evening, Sept. 5th, 1906. The meeting was called to order at 8:20 p. m. by President Arnold in the chair, and with about 50 members and guests present.

The reading of the minutes of the meetings of June 6th and 13th was dispensed with, as these had been printed in the August Journal.

The Secretary reported from the Board of Direction that at their meeting of July 3rd, 1906, the following were elected into membership in the Society:

| | GRADE. |
|---|---|
| Robinson R. Moss, Chicago, | Active |
| Chas. M. Wood, Palestine, Texas, | Junior |
| Edward B. Waite, Chicago, | Active |
| Elmer H. Olson, Texas, New Mexico, | Active |
| George W. Bunker, Grand Rapids, Mich, | Active |
| Otis Weeks, Denver, Colo., | Active |
| Floyd W. Place, Chicago, | Junior |
| Wm. F. Steffens, Bristol, Va.-Tenn. | Active |
| George M. Chandler, Chicago, | Active |
| Myron R. Stowell, Chicago | Associate |
| James H. Sawyer, Chicago | Active |

At the meeting of the Board of Direction of July 31st, the following were elected into the Society:

| | GRADE. |
|---|---|
| Dr. Wm. Michaelis, Jr., Chicago, | Active |
| Martin J. Kermer, Chicago, | Junior |
| Prof. H. J. B. Thorkelson, Madison, Wis. | Active |

At the meeting of the Board of Direction held Sept. 4th, 1906, the following were elected into membership:

| | GRADE. |
|---|---|
| Frank J. J. O'Byrne, Chicago | Active |
| Edward A. Paterson, Chicago | Active |
| George L. Griffith, Milverton, Ont. | Active |
| M. M. Fowler, Chicago, transfer from Junior to | Active |
| Wm. B. Weldon, Chicago | Junior |
| Chas. S. Holcomb, Chicago | Junior |

Also that the following applications had been received:

Edward C. Stone, Chicago.
Chas. E. Henderson, Parsons, Kans.
Wm. D. Richardson, Marysville, Kans.
Henry F. Treadway, Chicago.
Carlos A. Wiener, Chicago.
John C. Penn, Chicago.
Allen F. Owen, Chicago.
Arthur C. Smith, Chicago.
Vernon C. Ward, Chicago.

The Secretary made the announcement of the death of John Saltar, Jr., M. W. S. E., in Philadelphia, July 11th, 1906, and of A. W. Fiero, M. W. S. E., of Chicago at Battle Creek, Mich., July 28th, 1906.

Mr. Abbott offered a motion, for the appointment by the President, of Committees for the preparation of memorials of these deceased members of the Society, which motion was duly seconded and carried. The announcement was

also made of the lecture on "Panama, Past and Present," to be given the Society and its friends by Mr. W. J. Karner, M. W. S. E., the evening of Tuesday, Sept. 11th, in the Assembly Room of the Fine Arts Building.

There being no other business to bring before the Society, Mr. W. L. Abbott, M. W. S. E., was introduced, who presented his paper "Some Characteristics of Coal as affecting performance with steam boilers." Discussion followed from Messrs. W. T. Ray, L. P. Breckenridge, W. A. Shaw, Robt. F. Kuss, Edward H. Taylor, A. Bement, F. L. Jefferies, P. C. McArdle, E. F. Reynolds and W. H. Howe.

Letters were presented from Messrs. Albert A. Cary of New York, and Geo. H. Barrus of Boston, followed by a few remarks in conclusion from President Arnold and Mr. Abbott.

Meeting adjourned about 10:30 p. m.

## *EXTRA MEETING, SEPTEMBER 19, 1906.*

An extra meeting of the Society (No. 581) was held the evening of Wednesday, September 19th. The evening being stormy there was but a limited attendance. The meeting was called to order at 8:20 p. m. with Vice President Abbott in the Chair and about 45 members and guests present.

There was no business to bring before the Society, so Mr. Arthur S. Robinson, W. M. S. E. was introduced, who read his paper on "The Proposed 'Inner Circle' System of Chicago Subway Terminals." After the reading of the paper, discussion followed from President Arnold (by letter), C. V. Weston, M. W. S. E., H. B. Fleming, Engineer of the Chicago City Railway Co., George Weston, M. W. S. E., M. B. Starring, Gen. eral Manager of the Chicago City Railway Co., Walter L. Fisher, Counsel for Mayor Dunne in traction matters, with a closure by Mr. Robinson.

The meeting adjourned about 10:10 p. m.

J. H. Warder,
Secretary.

## *REPORT OF THE ENTERTAINMENT COMMITTEE.*

The Entertainment Committee arranged for a meeting, Sept. 11th, 1906, for an illustrated lecture by Mr. W. J. Karner, M. W S. E., on:

### Panama: Past and Present.

This was made a "Ladies' Night," and the meeting was held in the Assembly Room, Fine Arts Bldg., 203 Michigan Ave., Chicago.

The lecture was an enjoyable one, as it was "A Discourse of the history of the new Republic, its resources, the people and their customs, with some remarks on the Canal in 1904, and subsequently."

The evening was very warm and close, so that there was not the attendance that was looked for, only a few over 200 being present. But those that were there, expressed their appreciation of the evening's entertainment, which included refreshments.

An abstract of the lecture is printed in this Journal.

## CORRECTIONS AND ADDITIONS TO LIST OF MEMBERS.

*Corrections:*

Ahbe, F. R., 615 S. Main St., Athens, Pa.
Amari, Chas. A., Bridge Engr., Dyersburg Northern R. R., Dyersburg. Tenn.
Artingstall, Wm., Prin. Asst. Engr., in charge of Tunnel Lowering, Chicago Union Traction Co., Chicago.
Batte, Thos. R., Jr., Marietta, I. T.
Beye, John C., U. P. R. R. Co., Mena, Ark.
Binkley, Geo. H., 6916 Eggleston Ave., Chicago.
Brown, J. H., 569 28th St., Oakland, Cal.

Caldwell, A. J., The Marquette, Newburgh, N. Y.
Coates, F. Raymond, Vice Pres., Wallace-Coates Engineering Co., 612 New York Life Bldg., Chicago.
Coleman, Geo. P., Asst. State Highway Commissioner, Richmond, Va.
Davis, Uriah, Chicago Edison Co., 139 Adams St., Chicago.
Ewen, Malcolm F., R. 740 The Rookery, Chicago.
Forster, H. Walter, Engineer, Philadelphia Fire Inspection and Protective Bureau, Philadelphia, Pa.
Heck, Frank F., 78 La Salle St., Chicago.
Hill, Fred. L., Care Santa Fe R. R. Co., Belen, N. Mex.
Hubbard, L. L., Houghton, Mich.
Humphrey, F. W. L., 615 Rascher Ave., Chicago.
Johnston, J. P., Care Atlas Engine Works, Indianapolis, Ind.
Liedbeck, C. H., with American Bridge Co., Napa Junction, Cal.
Lurie, Arnold N., 506 E. Healey St., Champaign, Ill.
Marston, W. S., 199 Richmond Terrace, Port Richmond, N. Y.
Martin, Lewis M., Anita, Iowa.
Mason, L. B., 2217 Ilion Ave., North, Minneapolis, Minn.
McCullough, Ernest, 1304 Great Northern Bldg., Chicago.
Nicholl, T. J., Gen'l Mgr., Hudson Valley Ry. Co., Troy, N. Y.
Pence, William D., University of Wisconsin, Madison, Wis.
Phillips, T. C., with John W. Alvord, Hartford Bldg., Chicago.
Reichardt, W. F., 1201 Welch St., Little Rock, Ark.
Ripley, Joseph, Care Isthmian Canal Commission, Washington, D. C.
Tenny, M. W., Asst. Engr., Isthmian Canal Commission, Culebra, Canal Zone, Panama.
Townsend, Gilbert, Care Milliken Bros., Mariner Harbor, New York City.
Van Pelt, Sutton, Thorice, Mich.
Weber, Carl, Rudolstadt, Thuringia, Germany.
Worthing, Eugene, 239 W. Third St., Cincinnati, Ohio.
Young, Henry W., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Zinn, A. S., Res. Engr., Isthmian Canal, Canal Zone, Panama.

*Reinstated:*

Weston, George, with The Arnold Company, Chicago.

*Additions:*

Fowler, M. M., with Western Electric Co., Hawthorne, Ill., transferred from Junior to Active grade.
Gersbach, Otto, R., 400 La Salle St. Station, Chicago, transferred from Junior to Active grade.
Griffith, Geo. L., Res. Engr., Canadian Pacific R. R., Milverton, Ont. Active.
Henderson, C. E,, 216a N. Central Ave., Parsons, Kas. Junior.
Holcomb, C. S., 221 Schiller St., Chicago. Junior.
O'Byrne, Frank J. J., 996 Washington St., Chicago. Active.
Owen, Allan F., Engineer, National Fire Proofing Co., Chicago. Active.
Paterson, Edward A., 740 The Rookery, Chicago. Active.
Penn, John C., 455 W. 109th St., Chicago. Junior.
Richardson, W. D. Marysville, Kas. Active.
Smith, Arthur C., Asst. Engr., Morden Frog and Crossing Works, 618 The Rookery, Chicago. Active.
Stone, Edward C., Engineer, The Kelly Atkinson Construction Co., Chicago. Active.
Treadway, H. F., Sales Agent, Peerless Portland Cement Co., Chicago. Associate.
Ward, Vernon C., with North Works, Illinois Steel Co., Chicago. Junior.
Weldon, Wm. B., 1052 Fulton St., Chicago. Junior.
Wheeler, Herbert M., 875 Jackson Blvd., Chicago., transferred from Junior to Associate grade.
Wiener, Carlos Arthur, 402 Garfield Ave., Chicago. Junior.

*Deceased:*

Dobson, Franklin Pierce, El Paso, Texas.

## BOOK REVIEWS.

General Specifications for Steel Railroad Bridges. and Structures, by Albert W. Buel, under the direction of Virgil G. Bogue, C. E. New York, 1906. Engineering News Publishing Co. Paper, 8½x6 in. Price 50 cents.

In the preface the author states that the work is "written with the purpose of combining such rules, governing the design, workmanship, and quality of material, that steel structures built in accordance with them will be first-class in every respect, up to the highest standard of present practice, and at the same time as economical as is consistent with such results." And this requirement it seems to meet very satisfactorily. From it one should be able to select those special articles he requires to apply to any particular case, and the book should be found valuable for this purpose.

Section I, treats of preliminary plans, instructions to builders, etc.

Section II, treats of the general requirements as to material, type of structure, and details of design.

Section III, treats of loading, the loading adopted being Cooper's Class E-50. It also gives rules covering allowances for impact, centrifugal force, traction, momentum, and thermal forces where free expansion is not provided for.

Section IV, treats of permissable working stresses for tension, compression, combined stresses, shearing, and bearing, for both structural steel and timber. It also gives coefficients of friction for use in designing.

Section V, covers general details of design.

Section VI, treats of quality of materials and deals with the chemical and physical properties of structural steel, cast steel, cast iron, timber, paint and oil. It is noted that only oxide of iron paints are mentioned.

Section VII, treats of details of shop practice and workmanship; reamed work is specified for all main members, with drilling from the solid of all metal more than ¾ in. thick.

Sections VIII, IX, and X, treat of painting, inspection and erection.

Section XI, treats of Highway Bridges and of Buildings, giving general information as to roads, working stresses, etc.

In addition, diagrams are given for typical loading for railroad bridges and standard clearance, as well as tables of moments, and shears, etc.

W. E. A.

A Plumbing Catechism, or Theory and Practice of Plumbing Design, in question and answer, by Chas. B. Ball and H. T. Sherriff, Chicago, 1906. "Domestic Engineering" Publishers, 6¾ by 4½ in., 100 pp. Price $1.00. This is a capital little book that should be in the hands of all who have interests involved in Buildings to be occupied for business and residential purposes by human beings, where plumbing is required.

The book differs radically from the generality of such works by the use of the Socratic method of instruction, question and answer, and which in this case has decided advantages. The book is not divided into chapters, but a good table of contents, and a copious index makes it easy to look up any desired subject. The contents are divided into the main divisinos of Plumbing Fixtures, Water Service Pipes, Design of Pipe System, Effects of Freezing and Pumps. Under these headings there are numerous subheads to enable one to readily find what may be wanted. There are no illustrations, but this does not seem necessary, as the descriptions are clearly written, and the book does not attempt to show designs of work or apparatus.

The book does not touch on the handicraft of the plumber, as such knowledge can not be had from the printed page, but does expound the basic principles of design and practice, for the instruction of the non-technical reader. "It is good stuff!" W.

## MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Electrical Section—S. G. McMeen, Chairman, generally the 2d Friday of the month, October to May, inclusive.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

## NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

Journal of the
Western Society of Engineers

VOL. XI. DECEMBER, 1906. NO. 6.

## PUBLIC POLICY DEMANDS A WATERWAY SYSTEM.

A Discussion.

*October 12, 1906.*

*President Arnold*—We are fortunate this evening in not having any preliminaries and that we can at once take up the subject for discussion. It is an important one to the engineering profession of the country and we are happy in having with us some distinguished men in this line of work. I shall ask Mr. Lyman E. Cooley, whose name is known to all of you in connection with the great waterway systems of the country, to open the discussion.

*Mr. Lyman E. Cooley,* M. W. S. E.—I do not expect to occupy much of your time this evening, as there are others here, who have come from a distance, who will also address you on the "Public Policy of a Waterway System." I shall, therefore, restrict myself to a background for the picture which they are to paint.

In 1899 I undertook an investigation of the freight producing resources of the United States and of British North America, with special reference to the Great Lakes considered as an arm of the sea, and of the conditions under which commerce would seek lake ports.

At that time I discovered that the existing commerce of the Great Lakes was 29½ per cent., measured in ton miles, of all the railways of the United States: that the domestic commerce of the United States carried by water was about 87 per cent. (in ton miles) of that carried by all the railroads; that the over-sea tonnage, measured in ton miles, of commodities in the foreign trade was about 123 per cent. of that of all the railroads of the United States, and that the aggregate service of water to the United States as a means of transportation was about 2.1 times of that by rail. That is sufficient reason to justify consideration of these matters.

Take the United State as a geographical and topographical unit; we have some 3,000,000 square miles of territory which may be divided into four characteristic regions. The portion east of the Allegheny Mountains and east of Niagara Falls, if you please, extending from Maine to Florida, may be called the Atlantic maritime territory, having an area of about 375,000 square miles, or about 12½ per cent. of the total area, and an extreme length of

1,800 miles, and a width varying from 100 to 350 miles. Going westward, the Mississippi Valley lies between the Allegheny and the Rocky mountains, and includes the upper lakes system above Niagara, the valley of the Red River of the North to the international boundary, the Alabama river system as far east as Georgia, and the rivers of Texas. The upper lakes belong geographically and topographically to the Mississippi valley, and it is supposed to be a geological accident that they ever spilled over Niagara and down the St. Lawrence. Prof. Gilbert, of the United States Geological Survey, holds that there is a tilting in the crust of the earth, by which the outlet will be restored to Chicago in about 2,500 years. But Chicago has been forehanded in digging her canal in order to keep from being drowned out, and will no doubt be able to make sufficient enlargement to meet the conditions predicted by Prof. Gilbert as they shall develop.

The Mississippi Valley as thus outlined comprises 1,725,000 square miles of territory, or 57½ per cent. of that of the total area; about 1,600 miles long from north to south and about 1,700 miles in extreme breadth; the greatest valley with the most uniform topography, and the greatest single area that was ever spread out in one plain without barriers, for the occupation of man. You have comprehended in the Mississippi Valley and the Atlantic slope about 70 per cent. of the total area of the United States.

The Pacific maritime territory embraces about 5 per cent. of the total area, or some 150,000 square miles, a mere margin on the Pacific and a portion of the lower Columbia river basin. Between the Pacific territory and the Rocky Mountains is the great basin territory embracing an area of 750,000 square miles, or about 25 per cent. of the total, a country with little water and sparse drainage; a little in the north by the head waters of the Columbia river, a little in the southwest by the Colorado, and a little in the southeast by the Rio Grande; very elevated, and very sparse in resources.

Again, the United States may be divided into two equal parts, by a north and south line lying generally between the 97th and 100th meridian. This may be called the arid line, and divides the country on the east, which may be cultivated by dry tillage, from that on the west, which requires irrigation. This line leaves the Gulf of Mexico about longitude 97°, and crosses our northern boundary about 102° longitude. The average may be taken as 99½° longitude, west from Greenwich. The State of Kansas by statute has fixed the arid line at longitude 99°, west of which the waters are appropriated for irrigation, and east of which the ordinary riparian law of humid country obtains.

The half of the United States west of the arid line contains only 200,000 square miles with sufficient water to raise a crop without irrigation. This may be called the Pacific humid territory, and lies in the northern half of the San Joaquin-Sacramento basin, and northerly to the international boundary line, and in the lower levels

of the Columbia river basin. The arid territory comprises 1,300,000 square miles, and is largely an elevated region; some 560,000 square miles lying at an altitude of over 5,000 feet above the level of the sea, 660,000 square miles between elevations of 5,000 feet and 2,000 feet, and only 80,000 square miles at an elevation less than 2,000 feet. This territory is very poor in water resources.

In connection with my professional investigations in the state of Colorado, I have taken the trouble to estimate its water resources in some detail, and I found that the run-off of an average year on the entire state (an area of 106,000 square miles), could be carried in the Chicago Drainage Canal, and Colorado is one of the better "arid-land" states.

Various estimates have been made of the amount of land to be reclaimed by irrigation, ranging from 75,000 to 125,000 square miles. I have estimated, from a review of all accessible data, that 130,000 square miles may possibly be utilized if the water can be conserved and used in the most scientific manner. The Reclamation Service proceeds on the basis of about 75,000 square miles, or some 50,000,000 acres, which will give 1,250,000 small farms of 40 acres each, and carry a population of 6,000,000 to 7,000,000.

We will assume that the territory ultimately to be reclaimed by irrigation is 100,000 square miles. There are some 120,000 square miles of forest area, but a large proportion of this has no such forest growth as we recognize in the forest lands of the eastern humid section. There are some 220,000 square miles of wood lands, areas that are sparsely timbered, but in which the rainfall is too scant for a full growth. This 340,000 square miles is estimated as being equivalent to only 190,000 square miles of acreage humid territory. There are some 110,000 square miles of desert country without sufficient herbage to maintain a sheep to the square mile. The pasture lands may be rated on the basis of the number of cattle which they will carry per square mile, in comparison with humid territory, and on this basis the entire 750,000 square miles of so-called grazing land are not worth more than 160,000 square miles of humid territory. The total economic value of these 1,300,000 square miles does not exceed the equivalent of 450,000 square miles of humid territory, and the entire economic value of the western half of the United States is less than 650,000 square miles. In other words, we might eliminate 850,000 square miles of the United States entirely, if we could put the resources thereof on the remainder, and compress it that much, reducing the United States virtually to 2,150,000 square miles and have perhaps a more useful country.

My object in calling attention to the character of this region is to emphasize the fact that the waterway district of the United States lies largely to the east of the arid line, and the territory to the west, which is susceptible of waterway development, is limited to the humid section of 200,000 square miles, and to perhaps

300,000 square miles more in the basins of the upper Columbia and upper Missouri, which fortunately break well across the continent; and further, that a large percentage of the resources of this so-called arid region is tributary to these two great river systems.

I will say, further, that if you take the waterway territory west of the arid line at 500,000 square miles, the proportional development which can be made in it is much less than in the country to the east.

To the east of the arid line is the humid territory of the Mississippi Valley, an area averaging 1,000 miles in width and 1,100 miles in length from north to south, or a total of 1,125,000 square miles.

The western border, at the arid line, lies generally close to the 2,000 foot contour of elevation. The eastern border soon descends from the mountain region to elevations of 1,000 feet or less in the head waters of the river systems. The thalweg, or lowest line, extends centrally from south to north, reaching a summit of less than 1,000 feet in the Red-Minnesota Valley at Lake Stone and Traverse, descending thence northward to 720 feet at Lake Winnipeg and to sea level in Hudson Bay.

To the northeast is the branch thalweg with its summit at Chicago, with a height of less than 600 feet, or an altitude below the top of the Washington monument in the District of Columbia, and this altitude measures the height within 20 or 30 feet of the lake plateau extending easterly to Niagara; thence the descent is to the northeast and to the Gulf of St. Lawrence.

We have, therefore, two very remarkable locations for waterways of the first class; one by the Mississippi and the Red-Minnesota divide northward, to the river and lakes system of British North America and to arctic sea level; the other by the Chicago divide and the Great Lakes northeasterly to the Gulf of St. Lawrence, in the direction of Europe.

On this north and south base line we have a strip of territory 500 miles wide and sloping up to the 2,000 foot contour on the west, and some 1,400 miles long, threaded with rivers capable of commercial development. On the east we have another 500 mile strip well watered and filled with numerous streams, capable of development.

Within this territory some 15,000 miles of rivers have been actually navigated and considered worthy of improvement by Congress. There are some 7,500 miles of trunk streams, like the Mississippi to St. Paul, Ohio to Pittsburg, Cumberland to Nashville, Tennessee to Chattanooga, the Missouri, the Arkansas, and the Red; and some 7,500 miles of tributaries. Judging by the tributary streams which are listed in the state of Illinois, the mileage can be readily multiplied by three.

I have compared the area of Illinois, Wisconsin, Indiana and Michigan with that of France, which contains some 204,000 square

miles and a waterway development of nearly 8,000 lineal miles, or about one mile of waterway to each 25 miles of territory.

I have also made a similar comparison, taking the territory embraced by Wisconsin, Minnesota, Iowa and Illinois. I find this territory much more susceptible to development than is France, the topographical conditions being far more simple and the distribution of streams and of locations connecting head waters being far better.

If we take the countries of northwestern Europe we will find some 24,000 miles of waterways within about 560,000 square miles of territory, or a mile of waterway to each 23½ square miles. A similar system in the Mississippi Valley would mean a development of 50,000 miles. We now have 15,000 miles which are navigated after a fashion. It will not tax the mental capacity of anyone familiar with the conditions to project 12,000 miles of trunk lines and 20,000 miles of branches. We are to have a population of 200,000,000 by the middle of this century, and 120,000,000 of these people will be in the humid section of the Mississippi Valley, and we will have occasion for just such a system; also with a further growth of population there is practically no limit to the development that may be made. No section of the world is so well favored topographically, so well watered, so uniform in resources of soil, of climate and of minerals, and has such great extent as this same Mississippi Valley.

Passing eastward to the Atlantic maritime territory, the conditions are very different. This region is sub-divided into four divisions or compartments, or is segregated into distinctive provinces much like the countries of Europe. To the north is New England with 66,000 square miles distinctive and apart. Next is the New York Bay province of 84,000 square miles, embracing New York, New Jersey, and Pennsylvania, which constitutes the natural link for transportation between the west and the north Atlantic seaboard. Through this, by way of the state of New York, must pass a great future ship canal from the Mississippi Valley and the Great Lakes to the north Atlantic coast.

Next is the Chesapeake Bay system of some 100,000 square miles, embracing Maryland, Virginia, and North Carolina—a distinct entity, and almost isolated in its waterway possibilities, from connection with the west. To the south is the south Atlantic compartment and some 125,000 square miles, embracing South Carolina, Georgia, and Florida, and through these a link to the seaboard will some time be opened from the Tennessee river by way of Atlanta and northern Georgia.

Through a remarkable development of bays and sounds it is possible to connect the lower reaches of the river systems and thus produce a connected development for a portion of this area, but the rivers generally soon reach a high altitude as they approach the mountains, and the Atlantic maritime territory is not susceptible

of any proportional development to that of the Mississippi Valley.

I wish now to call your attention to some matters in connection with railroad transportation, yet very briefly.

In the last ten years transportation on the railroads in the United States, in ton miles, has increased about 117 per cent., or has more than doubled. The actual increase in mileage has been about 20 per cent. The density of traffic, that is the tons carried over each mile, has increased about 50 per cent. and perhaps 50 per cent. of the increase is due to new mileage. The number of tons transported, however, has increased less than 50 per cent.; it was June 30, 1904, about 611,000,000 tons, as against about 416,000,000 tons ten years before; that is for the total freight originating on all the railroads considered as one system.

The rates have not changed very much in the last ten years. They have run along at about 0.78 of a cent per ton mile, considering the railroad systems as a whole.

Of the commodities carried by rail, 52 per cent. is the product of mines, 40 per cent. of which being coal and the remainder ores, building materials and like products. The soft coal is worth at the mines about $1.00 per ton, the anthracite $1.50, and the coke about the same, so that we may assume the products of the mine generally to be worth from $1.00 to $2.00 per ton. In other words, what the consumer pays is far more for *transportation* than for original production. We may add 15 per cent. addition for coarse manufactures and forest products not exceeding in value $5.00 per ton, and the aggregate would be some two-thirds of the total transportation by rail.

The effect of a waterway system will be to largely relieve the railways of those coarse freights of low value, the cost of which will be reduced to the consumer by probably one-half. This leaves to the railways the more profitable, high-class freight, and the express, mail and passenger business. If we were to devote $100,000,000 a year to the construction of a waterway system we may well believe that no injury would result to the railway system, as the growth of commerce in recent years has been far greater than the facilities which could be provided.

Mr. James J. Hill, in his speech before the Commercial Association very recently, took the pains to observe that the growth of traffic in this country was so enormous that it would be impossible in the next ten years for the trunk lines going east to carry it without building new lines and increasing their terminal facilities enormously; and I think we can look to a time when it will be impossible for the railroads, on account of the cost of the increased facilities which they must provide, to lower their rates. In other words, they come to a point, as in the telephone system, where the cost of doing the business increases with the number of subscribers, and I think railway rates, especially in the forwarding business, will ultimately reach such condition that no radical reduction can be looked for.

If all the railway capital were to be eliminated today, we would not be able to reduce rates below the cost of operation and maintenance, and which amounts to 66 per cent. of the total receipts. If we take the cost of reproducing the railway system at one-half the present capital account, it would not be feasible to reduce the average rate by more than one-sixth. Such results are all that it is possible to effect by any legislation based on proper capitalization and a reasonable return, or on public ownership. So we must regard a waterway system as an absolute need of the future, with its growth of population and densification of traffic, and the development of resources in the coarser products.

On January 5th, 1886, I read a paper before this Society on a Rational Policy of Public Work. It was the beginning of a movement for a waterway system, and an organization specially constituted to carry it out. It was followed up by a bill in Congress, and for a couple of years a good deal of literature was produced on the subject. Within the last three years all the papers in the premises have been called for by the Chairman of the Rivers and Harbors Committee of the House. I dug them out of my dust bin and sent them to him, and again within the last three months the Commissioner of the Government of Japan called at my office and asked for another full set of these papers. He was on his way to Europe to study the very question which we undertook to study in this country twenty years ago.

A couple of extracts from that paper presented before this Society in 1886 are here introduced:

> "The canal systems of our fathers are of the past, and the day of meagre channels and small boats is drawing to a close. The railway is better adapted to the quick, detailed and distributive traffic of our country. Natural channel-ways, developed to a capacity suited to fleets and boats of large burden, so articulated at vantage points as to require no change of cargo—a great trunk system with tributary water-ways of indefinite extent, joining market points of heavy traffic origin and destination—this is the system of the future."
>
> "Waterways as at present existing, in detached lengths, unsuited to economical transport, unavailable a good portion of each year, cannot be expected to attain great results and yet their influence is admitted. Waterways should constitute connected systems as well as railways, and they should be so planned as to avoid trans-shipment as much as possible. The same capacity cannot everywhere be provided but improvements can be based on a few well considered types, uniform throughout the country, in lieu of present methods by detached works without reference to other works with which they will sometime constitute a system."

On the same general subject, a letter was addressed last year to the Chairman of the Rivers and Harbors Committee of the House of Representatives of Congress, which is here presented.

"CHICAGO, ILLINOIS, Feby. 1, 1905.

*Hon. Theodore E. Burton, Chrmn. R. & H. Com.—H. R. Washington, D. C.*

DEAR MR. BURTON: I am reminded of our discussion in regard to utilizing state and private energy and initiative in the production of a waterway system, and it seems to me that some definition on such policy may be opportune. The promptness and unanimity with which the House passed the bill for a dam at the foot of the Des Moines rapids, and the report to be filed soon on the deep waterway between Lake Michigan and the Mississippi River, and, above all, the disposition of public men to entertain some form of co-operative effort, leads to this suggestion.

The first step is to mature a comprehensive plan to which all efforts, individual, local, state and national, shall conform. There is now little unity in effort and purpose and millions are not only wasted, but barriers are constructed in the road of ultimate development, and even the works of the general government fail to show more than local unity.

I believe that we should have a system of waterways developed to the reasonable limit of the physical possibilities. I believe our knowledge is now sufficient to formulate an intelligent outline. We have data respecting the principal water courses of every basin and the routes by which they may be connected. The art of engineering is adequate and will expand with the opportunity; transportation conditions in their logical scope are becoming evident, and the great natural resources of the continent are now defined.

That the actual development will take a long time is not germane. It will be greatly expedited when the fields of effort are mapped out and the several interests know what is expected of them. There will be capital for every situation that invites water-power development; there are riparian lands to be reclaimed; there are harbors and improvements for benefits purely local, and states have purposes of their own to conserve. All such efforts can be stimulated and directed to a common end, and the aggregate may be greater than the work left for the general government. Help those who are helping themselves and you are sure to do something that is vital to the common welfare. There is no interest that can be enlisted that does not have the greatest concern in the general outcome.

The primary feature of any system is the backbone which must pass through the lake region and the Mississippi Valley. To what limit can this be developed now and in the future, and to what limit the laterals? There cannot be one gauge as in railways, but there can be a minimum unit and multiples thereof, so that water commerce need not break cargo any more than rail.

A commission should be composed of men of the broadest information and the most far-reaching outlook, and given a search warrant for all available information in the several departments of the Government; not job-hunters, not passive executive agents, pessimistic and fossilized by long office-holding,—something more than men of mere detail, hunting for precedents. Lord Wolsley has said that a great military commander is not born to a nation in every generation, and we may not have the men for such a problem.

I believe your general thought in this matter is the same as my own, and it is only a question of means to an end and the psychological moment.

I am sorry not to have had the opportunity to talk with you while in Washington.

Yours truly,

(Signed) L. E. COOLEY."

*President Arnold*—Our Past President, Mr. Cooley, has given us an excellent and very comprehensive outline and discussion of the subject we are considering this evening. I will now call upon Mr. Charles T. Harvey, of Toronto, Canada, who built the first canal at Saulte Ste. Marie in 1853-5. Mr. Harvey attended the celebration of the semi-centennial of that opening of that canal last year and has seen the commerce of Lake Superior grow from the hauling capacity of half-a-dozen teams of horses to 44,000,000 tons.

*Mr. Charles T. Harvey*—Sometime ago, when I looked at a map made by our friend, Mr. Cooley, showing the different waterways and basins of which he has been giving us the dimensions, I felt fearful that he had made a mistake. His map indicated that the basin of Hudson Bay came within twenty odd miles of Lake Superior. This map first drew my attention to that fact, and I thought that it was such a remarkable geographical condition that I would not accept his statement, so I took a compass and went over the ground myself on foot, and found his map to be correct, and that the distance between Lake Kenogima, which is 55 miles long on the outer edge of the vast basin of Hudson Bay to deep water in Lake Superior, to be less than twenty-five miles.

While of late I have been hailing from Canada, the greater part of my life has been spent in the United States, and I yet consider myself a "simon pure" Yankee, with a continuous allegiance to the Stars and Stripes. But I became very much interested in the status of waterways in Canada, and will briefly refer to that subject in advance of the topic which your President has alluded to, my connection with the first ship canal on the lakes.

In studying the maps of Canada I found that there was an enormous system of waterways in the region known as the MacKenzie River Basin, comprising nearly 10,000 miles of navigable lakes and rivers therein. Concluding to explore it a little personally, in 1898

I went to Edmondton, chartered a buckboard wagon and team, drove northward 125 miles, and then launched a boat on the Athabaska river, of that basin. At the "Landing" where I reached that river, there was a flotilla of boats belonging to the Hudson Bay Company, on which I saw packages marked for trading "posts" beyond the Arctic Circle and also for Fort McPherson near the Arctic Ocean. Those packages were going through on the waterway system now in use, nearly 2,000 miles northward, with but two transfers around falls and rapids between navigable sections on which steam tow-boats are employed, and with no other obstructions north of the Great Slave river to the Arctic Ocean, a distance of about 1,300 miles.

I found upon further investigation that if you will start from Chicago via Lake Michigan and add to the present waterways thence northward less than 500 miles of railway, to connect the water courses, you can go from here to the farthest point of Alaska in probably less time than you can go by way of the Pacific. Just think of it! Only 500 miles of connecting railways to bring Chicago into commercial access with Alaska via an interior line of waterway transportation extending to the farthest boundary of the United States! That I think is to be one of the marvels of the future growth of our continental waterway facilities.

But now referring to the present topic, will say that I had the experience of going up to Lake Superior in 1852 as an invalid seeking health, and when at its outlet, I saw all its business done with six or eight spans of horses for transferring supplies to the mines and their products in return, around the Falls at Sault Ste. Marie. All the commerce on the greatest of lakes then passed over the plank road or strap railroads at that portage, with the minimum of horse power before mentioned!

In going through the mining camps of the upper Peninsula of Michigan, I saw some of the mineral developments which filled me with wonder and surprise. One was a 500 ton mass of native copper that was 98% pure, and it was reported as costing a quarter of a million dollars in labor to cut it into pieces of suitable size for shipment I saw the first iron mine opened there, of specular iron ore, which shines almost like silver; then it was the only mine-opening of that kind in that region, and which was about the size of this room. The discovery of the extent and value of the hematite iron ore mines was in later years.

On returning to the "Soo" I wrote to my principals, Messrs. E. & T. Fairbanks & Co., of St. Johnbury, Vermont, and told them what I had seen in the mining district and also of the fact that the Congress of the United States had recently passed an act donating 750,000 acres of land to the State of Michigan to aid in building the "Sault" canal. If you will consult the Congressional records you will find that Henry Clay opposed that grant, stating that to build a public work so far away, in a remote corner of the United

States, was like trying to build something to reach the moon;—nothing of that kind would be beneficial so far away! That is in the record of one of his speeches. He was a very patriotic man, and a statesman who intended to do what was for the interests of the country, but his range of ideas was so narrowed by his own experiences and environments that he did not grasp the possibilities of the future for the west. And I think our friend, Hon. Mr. Ransdell, the member of Congress from Louisiana, who is with us tonight and is giving his attention to this over-shadowing subject,—the extension of our national waterways,—occasionally, finds men now in Congress who fail to take in the whole scope of future expansions of commercial and industrial interest now reaching from Maine to Louisana and from Texas to Alaska. They only look at the size of their own bailiwicks and do not understand that this is a continent that has to be managed in due proportions.

I wrote to my principals that the building of the Lake Superior canal would add immensely to the value of the lands in that mineral district, and that I thought there was a great financial speculation as well as vast public benefits to accrue from its installation, and I would like to have them grant me permission to see if I could not get suitable laws passed to facilitate its building, they to become interested as inventors in its construction.

Rather to my surprise, in a week or two, I received their reply, stating that they approved of my request, and approved of my attending the Legislature of the State of Michigan to see what could be done, and to draw on them for my expense. On going to Lansing, the state capitol, I found that the Committee on this matter consisted mostly of farmers, very honest, well-intentioned men, but they did not have much idea about ship canals, or the location of that one. Said one of them, "Young man do you know anything about the place they call he 'Sue' Sainte Maria? Is it near the big lake called Lake Superior?" In such crude ways some of them sought additional information. Their chairman, however, was a land surveyor of wide experience and special ability. Eventually the committee requested me to draft the law to provide for building the canal, which was passed precisely in the form which I submitted. The question of the dimensions of the locks was the main subject of discussion; I advocated a cantal to Lake Superior with a capacity for the largest steamers then on the lower lakes, asserting that the time would soon come when the commerce of that lake would warrant those dimensions. Consequently the size of the lock proposed was 70 ft. wide and 350 ft. long. No engineer then thought it would be practicable to use a single canal life-lock of eighteen feet elevation.

There was none so high on the Erie Canal and that was the accepted gauge of canal lock proportions. Thus limited, the 18 feet fall was divided into two lifts. It was to be what is known as a "tandem lock" canal, to lift nine feet in each lock. When the

bill was thus reported, a letter came to the Committee from the then largest individual steamboat owner on the lakes, Captain Eben B. Ward, of Detroit, stating that to build locks of that size was simply a waste of money and would involve extra cost sufficient to endanger the building of the canal, urging the Committee not to authorize such an extravagant size, when locks 250 ft. long and 50 ft. wide would be ample capacity for all commercial purposes. A meeting of the Committee was held, and I was called before it; the letter was read, and my comment requested. This was that my principals, I believed, were ready to build the canal locks of the larger size, but if the Legislature preferred the smaller size, it then must designate the same in the "bill." The Committee's conclusion was that the larger locks, without extra cost to the State, were preferable, and those dimensions were finally adopted. When the contract was awarded to my principals and they became incorporated, they appointed me General Agent of the Construction Company, and under my supervision a steam-boat was chartered at Detroit, and loaded with men and supplies for the work.

I had the honor of "breaking ground" June 4, 1853, with the first barrowful of excavation, which I wheeled out, to commence the canal work.

Navigation on the St. Mary's River then, was such that in midsummer a lower lake steam-boat that drew over eight feet of water could not reach the Falls. Now twenty foot draft steamers go through that river, although by another channel, which the Government has since excavated south of Sugar Island.

The canal was finished in the spring of 1855, or in less than two years' time, during which I had charge of the work, and had the privilege of hoisting the coffer-dam gate and letting water from Lake Superior flow into the canal for the first time, April 10th, 1855. It has never been out since, and will probably continue thus as long as the world exists.

I have here the Government report of shipments through the canal up to date. In 1855, the year that the canal was finished, the shipment of iron ore was fourteen hundred and forty-seven (1,447) tons. Last year it was thirty-one million, two hundred and thirty-one thousand (31,231,000) tons, and the whole business of the canal, including grain and other freights, both ways, amounted to over forty-four million (44,000,000) tons, with a value of over four hundred millions of dollars ($400,000,000).

The effect of that canal has been to enable the United States to forge ahead of all other nations of the world as an iron and steel, or rather as a metal producing country; this including copper as you all know. The cost of transferring that enormous product through the canal is officially stated to be about one-fourth of one mill per ton! The cost of transferring a ton of freight around the Falls alone, before the canal facilities were there was about three dollars a ton!

The entire expenditure on the construction of that canal, estimating the average population of this country at seventy millions, for the first half century of its use, amounts to less than twenty cents per capita!

When I was attending the celebration last year at the "Soo" of the Fiftieth Anniversary of its opening, the speakers stand was near by the main locks of the canal, and while orators were addressing the audience, several steamers were locked through, some carrying about ten thousand tons of ore, and without making noise enough to interrupt the speakers! The canal on the American side is operated by hydraulic power; by which the gates are opened and closed. On the Canadian side electricity is used. There the lock tender simply touches an electric button, and thereby fills or empties that lock, nine hundred feet long and sixty feet wide in about six minutes! Can you think of any result in the whole range of human achievements more grand than this? The construction of these canals and locks ranks high among the great achievements of our age.

I was much impressed this summer, coming through from Buffalo to my summer home on Lake Superior, with the changes that had taken place in the lower lakes passenger traffic, particularly on Lake Erie.

For twenty-five years or more, the steam-boats were discontinued as a means of passenger traffic between Detroit and Buffalo. It is only within the last few years, perhaps ten or even less, that there has been a regular line of passenger boats between those cities. In olden times the Michigan Central Road stopped at Detroit, and one had to take a steamer to Buffalo, but later on the extension of the railroad was supposed to do away with such use of the lake waterway.

The steamer that I came on from Buffalo to Detroit in the latter part of last August had a capacity of thirty-five hundred passengers, and while I was fortunate enough to get a stateroom for myself and wife, there were scores of people that could not get berths, and who were compelled to sleep on the cabin floor. This indicates that waterways can yet hold their own, in competition with railroads, to a very large extent. When I was in Detroit lately a merchant there told me that some five thousand tons of freight waited at Buffalo for shipment to Cleveland and Detroit, and was accumulating faster than it could be forwarded.

Those facts prove what waterways are worth to us at the present time. When I was down the Mississippi about a year ago, and saw those tandem processions of coal barges being towed through from Pittsburg via the Ohio, and the Mississippi to Memphis and beyond, I could think of no grander engineering aim than to facilitate commerce by canalizing the Ohio and other rivers, and otherwise improving a system of transit so capacious and so economical. In conclusion I have to say that in my judgment there is

no more patriotic or beneficial service to be done in the United States, at the present time, than to enlarge and improve our national or a general system of waterways.

*President Arnold*—Mr. Harvey, in the course of his interesting and instructive remarks, made reference to a gentleman who has labored with this problem in the national House of Representatives. He will be our next speaker on this subject. He is a member of the Rivers and Harbors Committee and Chairman of the Executive Committee of the National Rivers and Harbors Congress, the Hon. Joseph E. Ransdell, of Louisiana.

*Hon. Joseph E. Ransdell*—I feel very much abashed in attempting to make a speech to you on this subject, after the addresses of two such distinguished men, one of whom, (Mr. Harvey) constructed one of the greatest engineering works of his age—the first lock at the "Soo"—five years before I was born.

The last speaker has told you that I would elucidate the benefits of water transportation, and the first speaker showed you in very forcible language the possibilities of water development in our country. I heard two days ago a speaker at the Minneapolis convention for the improvement of the Upper Mississippi River, say, that in his judgment, this would not longer be called the steel age, but the water age; that he believed the near future was going to show marvelous development of our waterways. He expressed an idea which I have been trying in my humble way to carry out, the gospel which I have been trying to preach from one end of this union to the other: That it is the proper thing for the American people to develop their waterways to the very utmost.

As you are aware, the National Government has not done much toward developing our waterways. In the whole history of our nation only about $470,000,000 have been spent to improve all the rivers, lakes, and harbors in this great country. During the past ten years the average annual appropriations for these purposes have amounted to about $19,250,000. When you consider the magnitude of our waterways as explained so forcibly by Mr. Cooley; when you consider the enormous lake line and ocean line, and gulf line, and the vast interior river systems of this country; when you consider that we now have nearly eighty millions of people, you must admit that that is a ridiculously small sum.

I have appreciated that fact very forcibly for the past five years as a member of the Rivers and Harbors Committee of the House of Representatives, for we have had pressed upon us with the greatest vigor and force a very large number of projects calling for an expenditure of over $500,000,000 and we were asked to provide for them at the rate of $19,250,000 a year. Now, gentlemen, I ask you as business people how would you do that, if you were all members of the Rivers and Harbors Committee? Here you have $500,000,000 of waterway projects before you,—aye, more than $500,000,000, and a constantly increasing list, and the party leaders in

the National House of Congress tell you that you must not spend more than $19,250,000 a year.

It is a very difficult problem. It is a problem which we have been utterly unable to solve. It cannot be done, and we have not done it. We have tried and failed; we have met around the table in the Rivers and Harbors Committee room, and with the engineers reports lying before us showing all these vast projects and we have had to eliminate here, and cut off there, making entirely inadequate appropriations for the projects that we did take up, and leaving off entirely the greater majority of those projects. That has been our work; that has been what we seemed forced to do by the sentiment of the American people.

I do not wish to place my colleagues in Congress in a false position. I know that the Rivers and Harbors Committee were very anxious to make a reasonable and proper provision for all the waterways of our great Republic, but the sentiment of the people of the union did not seem to be back of us; did not seem to be in favor of making any larger appropriations than we were making, and as servants of the people we had to carry out their behests.

Now the association that I am connected with, the National Rivers and Harbors Association, has for its purpose the building up of a sentiment throughout the nation in favor of a broad and liberal, a truly national policy, so that Congress will be induced to spend sufficient sums annually, to properly provide for and improve every meritorious waterway in the land. After being on the Rivers and Harbors Committee for several years, and seeing people come from every section of the country, vying with each other in the most vigorous and energetic way for their share of the small sum which was being appropriated: seeing how utterly impossible it was to take care of these waterways out of this parsimonious sum, I conceived the idea of uniting in one great national body every friend of waterways in this union, to the end that being together pulling together, pulling with that long pull and strong pull and pull altogether, as they say at sea, we, the friends of the waterways of this union, might pull Congress into our way of thinking and make it adopt a broad, liberal policy toward our waterways instead of the parsimonious one pursued since the foundation of the Government.

With that end in view, with a number of others, I was instrumental in calling a great national waterways convention in the city of Washington last January. That convention was composed of a number of the very best men in this nation: men from every part of the United States: leaders in business life, leaders in professional life: leaders in engineering life, and in every kind of business and in every calling. They met there, and after consulting and devising for two days, resolutions were passed denouncing in unmeasured language *the policy of Congress toward our waterways as niggardly and parsimonious in the extreme: declaring it to be*

*the sense of that convention that in the future we should have an annual River and Harbor bill instead of one in every three years as we have had for the past ten years, (one being in 1899, one in 1902, and the last in 1905); and declaring that we must have at least $50,000,000 a year.*

To carry out the purposes of that convention an executive committee of fifteen was appointed with plenary power to take whatsoever steps to them seemed best to arouse the sentiment of the American people on this subject. Since that time this committee has done its best to carry on a publicity campaign from one end of the nation to the other. We have sent speakers all over the country. We have had men visit practically every one of the great cities in the land to try to induce the commercial bodies there to organize. We have formed a great organization. There are now thirty-six states represented in our body. We are doing a great deal of publicity work. We are to have a great national convention in Washington on the 6th and 7th of December next, and at that time we hope to be able to demonstrate to Congress that the sentiment of the American people is aroused on this subject; that we are not satisfied any longer to have $19,250,000 for our waterways, but are determined to have at least $50,000,000 a year for their improvement.

Now, gentlemen, do we need this $50,000,000 a year? Would it be a wise expenditure? Would it or not, be a "raid on the treasury" for Congress to appropriate $50,000,000 for our waterways? I hardly think it necessary to discuss this question, and yet I know you expect it of me. We know things in this life by comparison; now by comparison with the other great items of expenditure, the sums appropriated for waterways are certainly very small. As I have stated the waterways have received an average of $19,250,000 a year for the past ten years. During that time the navy has received about $67,900,000 per year; the army $69,700,000; the postoffice department $127,300,000; the pension department $143,200,000 per year. So you see that if we are given the $50,000,000 which we ask we will still lack a great deal of being on a par with the army, the navy, the pensions, and the post office. We will be still far below them.

Another way of expressing that is this: the total average annual expenditures for all purposes of government for the past ten years have been $712,000,000 a year in round numbers. Of that sum rivers and harbors have received a fraction under 3%. Think of it; $712,000,000 spent every year and rivers and harbors receiving less than 3% thereof. Is not that a ridicuously small sum for developing the commerce of our country? Especially when you consider that all of that $712,000,000 comes to the Government from commerce and agriculture, which is very closely akin to it. Commerce enables the Government to reap this $712,000,000, and yet to commerce is returned less than 3%.

How do we treat war and its rewards, in this peace loving country of ours? Fortifications, a little over $7,000,000, and as I have stated to you, to the navy $67,900,000, to the army $69,700,000, to the pensions $143,200,000, totaling over $280,000,000,—over 40% of the whole. War and its rewards, in this peace loving time; over 40%, and commerce, in this, the greatest commercial nation on the globe less than 3%. Does it seem to be giving us a square deal? You know it is not.

Now, would it pay? *I state, without fear of successful contradiction, after having studied the question as deeply as my ability enables me to study any subject, that the average cost of transportation by water as compared with transportation by rail is only about one-sixth; rail transportation is fully six times as high as that by water. I further state, without fear of contradiction, that every dollar invested by this government in improving its navigable waters, or in making navigable waters by canalizing streams not now navigable, and by constructing transverse canals, will return to the citizens of this Republic every year at least 200% on the amount so invested.*

I know that unless you have studied it, this sounds like a hard saying, and many of you will say, "Can he prove it?" Let us take the commerce on the great Sault Ste. Marie Canal with which our distinguished visitor was so closely and so honorably connected many years ago, before a great many of us were born. He has told you that the commerce passing through that canal last year—1905—was a little over 44,000,000 tons. Let me add that it was valued at $416,000,000. The freight on it was $31,000,000. The average distance it was hauled was 833 miles, and the average cost of transporting that great commerce per ton mile was 0.85 of one mill!

Now, I have tried very hard to find out the exact average cost of transporting frieght on the railroads paralleling the lakes. The average cost on all the railroads of the United States last year was something like 7.80 mills per ton mile. As well as I can gather it the average cost of transporting freight on railroads immediately adjacent to and coming in contact with the great lakes was about 4 mills per ton mile, during the year 1905.

If we apply that ton mile rate to this great commerce—this 44,000,000 tons of freight—the charge thereon instead of being $31,000,000 as the water rate was, would be $147,000,000, or a saving by water of $116,000,000 on the commerce passing through the Sault Ste. Marie Canal during last year.

But, that is not the only saving. Remember that the average charge of the railroads in the United States last year was nearly eight mills per ton mile instead of four mills, as I have credited them with where they paralleled the lake, and remember, too, that not much more than half of the commerce of the great lakes passes through the Sault Ste. Marie Canal. There is an immense com-

merce which never sees that great work. So, if we can show a saving there—an actual saving on the actual commerce passing through, of $116,000,000—we are certainly justified in saying that the indirect saving because of the reduced rates on the railroads, and the direct saving on the other commerce of the lakes besides that passing the "Soo" is another $116,000,000.

Now, what did the Government pay for all these improvements on the lakes, not only the Sault Ste. Marie Canal, but every other channel and every harbor on the lakes? A little less than $70,000,000 has been spent by our Government on these lakes in its entire history. And yet, I think I have demonstrated to you, and I ask you to examine the figures of the report of Col. Charles B. Davis, the United States Engineer in charge at Sault Ste. Marie, and any other authorities you can find on that subject; I ask you to examine them and see if I have not told you the truth when I state that the saving to the American people last year on freights was over $232,000,000 because of that total expenditure by the Government of $70,000,000.

Let me give you another little incident that occurred before our Committee in Congress about three years ago. You are all more or less familiar with the Monongahela River; you all know that the great iron mines up on the Mesaba Range near Lake Superior furnish the ore to the furnaces at Pittsburg, and you know that Pittsburg receives its coal supply by the Monongahela River; the supply of coal last year amounted to about 10,900,000 tons. That little river was first canalized by private enterprise and afterward bought by the Government. It has cost the Government about $6,900,000, and its commerce last year was 10,900,000 tons.

Three years ago there appeared before the Rivers and Harbors Committee, Mr. B. F. Jones, of the firm of Jones & Laughlin, of Pittsburg, who are very large manufacturers of iron and steel, employing from 7,500 to 8,500 men, and using 1,500,000 tons of coal annually. Mr. Jones was there to talk for new locks in the Monongahela River. He was there to urge the replacement of one of the old locks which was threatened with destruction, and he made a most vigorous talk before us. We asked him, among other things, what it cost him to convey coal from the mines to his factory in Pittsburg. He hesitated; he said, "Mr. Burton, it looks to me as if that would be disclosing a trade secret, I do not think I ought to be forced to answer that question." But, any of you who know Mr. Burton know that he is a very far-sighted and insistent person; and when he had a chance at Mr. Jones he very properly used it to find out this "trade secret." Mr. Jones finally acknowledged that it cost him from 3½ cents to 4 cents per ton to convey that coal from the mines to his iron works. Not per mile, mind you, but per ton; an actual cost of 3½ cents to 4 cents per ton. He did not give us the number of miles exactly, or I would give it to you. We then asked him what would be the result if anything

happened to those locks; if the Monongahela River should freeze over or the locks should cease to work. "Why," he said, "the railroads would immediately charge me 44 cents per ton, or from eleven to twelve times as much." The water rate there, being, as you see, from 1,100% to 1,200% cheaper than the railroad rate.

We further asked him if he could get his supply by rail. "No," he said, "I cannot get my supply of coal by rail. That is one of the very troublesome questions with me even if I am willing to pay this 44 cents per ton for getting that coal," (and charging it to the good people of Chicago who use such quantities of the product of Jones and Laughlin's works of structural iron and steel)—"even if I am willing to pay that 44 cents per ton instead of 3½ cents per ton I cannot get the coal. The facilities are not there."

Now, think of what that means; the difference between 3½ cents to 4 cents and 44 cents; in other words a saving of 40 cents per ton to him; to me; to you; to the American people, who consume coal and use its great adjunct, steel in the thousand and one forms that we use it. A saving actually of over $4,000,000 a year to the American people on the coal passing through that little river.

Can any man hesitate for a moment in response to the question as to whether or not that was a wise expenditure of money? Surely not! Certainly it was wise if it saves us four million dollars every year! Certainly the expenditure of $70,000,000 on the great lakes was wise, if it saved the people $232,000,000 last year, as I have shown you.

But, is that all it saved them? No, for let us look at it in a little different way. Let me imagine for a moment that I am addressing now the farmers of the seven great states immediately tributary to these lakes: Ohio, Indiana, Illinois, Wisconsin, Minnesota, Michigan and Iowa. I count in Iowa, though it is not, as you know, exactly connected. During the year 1905 the cereal crop of those seven states, that is the crop of oats, wheat, rye, barley and corn, was 1,977,000,000 bushels. Now, what was the price of freight charged on a bushel of grain in the early sixties, when the lake channels were only twelve feet—I believe that is what the "Soo" canal provided for, as at first built.

*Mr. Harvey*—Twelve feet, yes.

*Mr. Ransdell*—In the early sixties when the depth of the harbors and connecting channels on the lakes was twelve feet, the freight charge on a bushel of grain from the city of Chicago to the city of New York, via the lakes and the Erie Canal was 29.60 cents. It cost 46.10 cents per bushel in those days to convey a bushel of grain by rail from here to New York. What is the cost now? Though of course these rates fluctuate a little—the last figures I have show that the rate is 5.25 cents per bushel, from here to New York by water, and 10.20 cents per bushel by rail; a saving of over 24 cents per bushel on the water rate of forty years ago, and a saving of 36 cents per bushel on the rail route of forty years ago.

But, do not take these big figures; let us take the difference be-

tween the present rail rate and the present water rate today of about 5 cents per bushel and assume that the farmers of these seven states were enabled last year to ship their cereal crops at five cents per bushel less because of the improvements on the lakes. How much would that be? About $97,000,000 on their cereal crop of 1,977,000,000 bushels; those seven states also raised about 87,000,000 bushels of potatoes, and about 23,000,000 tons of hay, and their saving of 5 cents per bushel on potatoes and 20 cents per ton on that hay, would be another saving of about $9,000,000, or a total of something like $106,000,000.

This does not take into account the innumerable other products of the farmers of these seven states. It makes no account of the innumerable manufacturing enterprises of these seven states, the wealth of their mines, and their enormous shipments of merchandise. There is a direct saving of $106,000,000 on the cereals, potatoes and hay alone.

But you may say, "Mr. Ransdell, hold on a moment. The farmers do not sell all of their cereals, hay and potatoes. They use most of that hay at home; they use a great deal of those oats at home." Yes, that is true; but you know as well as I do, that *the price of any product is fixed by the price of the surplus.* You know that the price of the wheat, the oats, the corn and other products which our farmers have to sell is the price in the best market in New York or Liverpool, and that the farmer receives for it the best market price, less the cost of transportation from his farm to that market; so, that whether he ships it or uses it on the farm, he gets the benefit of that five cents per bushel saving in transportation. There is no question about that. He does not need to sell it in order to get the benefit of that saving; it is worth that five cents more on the farm.

Is that all? No, for it is a generally accepted axiom of political economy, that the freight charge on agricultural implements, and machinery and the various and sundry articles and merchandise which the farmer purchases with the proceeds of the sale of his farm products and carries back into the farming country, is in round numbers twice as much as the freight on the outgoing farm produce. Now, if the saving in freight on the outgoing products of the farmers of these seven states was $106,000,000, the freight saved on the incoming products, bought by those farmers and carried back home would be twice that sum, or $212,000,000; and, when you add that to the original $106,000,000 you have there a total saving in 1905 of $318,000,000 to the farmers of those seven states alone.

But, is the effect of the Erie Canal, and the Great Lakes, and the Sault Ste. Marie Canal confined to these seven states? No. By no means. One of the greatest masters of transportation, in this country, the late Mr. Albert Fink, said that the great lakes and the Erie Canal affected transportation rates from Chicago to

the Gulf of Mexico; and he explained that in this way: He said that in the immediate vicinity of Chicago the railroads must compete, or reasonably compete with the water rates, or all the freight would go by water. When you get to the vicinity of Indianapolis, St. Louis, Cincinnati or Louisville, if the people there attempted to ship direct to Philadelphia or Baltimore and the railroads charged them too much, they would immediately ship by the short haul up to Chicago and thence by way of the lakes, and the Erie Canal to New York, and there would be no business for the railroads going directly east; so, the railroads going directly to Philadelphia, Baltimore, and the other Atlantic ports, were compelled to meet the competition which was made by the improvement at the Sault Ste. Marie Canal, and the Erie Canal, and all of the railroads south of the Ohio were affected by the competition of the lines north of them. Therefore, the improvement of these waterways affects transportaton not only in this great western region, but all down the country to the Gulf of Mexico.

Gentlemen, I might elaborate further on this subject, but there are others to follow me, and I do not wish to take up too much of your time. The question of a rate bill is often considered in connection with the improvement of our waterways, and the attitude of railroads toward waterway improvement is a very vital question at this time, and about which there is much discussion. Now I wish to say that I have never seen any direct opposition on the part of the railroads toward waterway improvements.

I wish to suggest this thought to you: what are the great ports of this country, but railroad terminals? Take New York for instance; see the number of railroads which terminate there. And again Boston, the great lines run in there and debouch their enormous train loads into large vessels which carry those cargoes abroad. The ports of this country on which a very large percentage of that $470,000,000 has been spent are absolutely essential to the railroads; they are part and parcel of the railroads, and I am told that the railroads are very largely interested in the big ships which ply into those ports, so that branch of the Government improvement of waterways the railroads would certainly help us to carry on. I know as a matter of fact, being a resident of Louisiana on the banks of the Mississippi river, in that great region where we have such disastrous overflows, that the very best friend of the Lower Mississippi is the Illinois Central Railroad, which has one terminus in this city and another terminus in the city of New Orleans., The Lower Mississippi River, the harbor of New Orleans, and the Levee system of that river has never had a better friend than Mr. Stuyvesant Fish, the president of that railroad. Moreover, the Southern Pacific, the Texas Pacific, and the Missouri Pacific have all been staunch friends of the Lower Mississippi.

I am reliably informed, too, that, when the people of the Empire

State of New York, about four years ago were voting a bond issue of $101,000,000 to enlarge and deepen their great Erie Canal to a depth of twelve feet, with sufficient capacity in the locks to float vessels carrying at least 1,000 tons burden, the New York Central Railroad, which parallels the Erie Canal for about 375 miles, voted for and supported that bond issue, although it is the largest tax payer in the state of New York. Why? The broad minded, far-sighted men in control of the New York Central railroad took the position that the further enlargement of that great waterway which had made New York the Empire State, and has given to New York City a lead over all the other cities of this nation, was wise in the extreme and that if it was carried out in the same spirit which originated it there would be such a vast influx of people along the banks of that canal, such a tremendous building up of all kinds of manufacturing enterprieses, so much high class freight would be manufactured, so many additional passengers would have to be carried, that it would profit the railroad as a business proposition to pay its share of the taxes and allow the canal to carry the extremely heavy freights which Mr. Cooley speaks of, while it carried the high class freights and passengers; so the railroad voted for that bond issue.

I think we ought to bear these facts in mind when we are talking about the improvement of our waterways, and we ought to get together, the waterway people and the railroad people, ought to get together and bring about a magnificent development of all the waterways of our entire country.

I wish to say just a word about the rate bill, because a great many people think it is going to prove a panacea for all the transportation ills of this country. I cannot imagine that the intelligent audience before me thinks any such thing. If you do, I wish to say you are going to be sadly disappointed. That bill is a very wise one and if properly executed will have a most beneficent effect in preventing rebates and discriminations. But there is only one way to regulate railroad rates, and that is by the immutable laws of supply and demand; by legitimate strife and competition between them and carriers on the free waterways which the Creator of the universe has given to His children for their use and benefit.

I, for one, my friends, have far more confidence in the competition on those waterways, in the legitimate strife on those unmonopolized and unmonopolizable waterways (if you will permit that word) than I have in billionaire railroad trusts regulated and controlled by a fallible and susceptible railroad-rate commission of nine or ten men.

Now, let me give you just a concrete case about a rate commission that has been working for a good many years. You have heard or read of the Railroad-Rate Commission of the State of Texas. You know that Texas is a very proud state. It thinks that it is a mighty empire. It is an empire in domain, and it con-

tains a good many proud and highly intellectual people. Many years ago its legislature, which is a body of unlimited powers, whereas our Congress is a body of limited powers, created a railroad rate commission, and gave to it all the powers which its constitution and laws permitted it to give. The sentiment of Texas is in favor of that commission. The courts of Texas are in favor of the commission, and yet in spite of that commission, in spite of the sentiment of the people, in spite of the courts, in spite of the law, in spite of everything, the people of the Dallas section, the center of the most magnificent cotton region in the world have for years ben compelled to pay an average freight rate of $3 per bale to transport every bale of their cotton,—amounting to about 1,500,000 bales a year,—to the city of Galveston, their seaport, a distance of about 300 miles. These are actual facts. It costs the people of Northeastern Texas, that raise annually in the neighborhood of 1,500,000 bales of cotton, $3 a bale to get their cotton to Galveston, and everything else, ingoing and outgoing in the same proportion.

Now compare that with the people over on the Mississippi river where I live, about 300 miles from New Orleans. I have personally shipped a good deal of cotton at fifty cents a bale; sometimes seventy-five cents per bale, and never more than a dollar; and I have known cotton to be shipped from Cincinnati to New Orleans, 1,500 miles, at a dollar per bale. It is not at all uncommon, in fact it is an every day occurrence for cotton to be shipped from Memphis to New Orleans, five hundred and odd miles, at one dollar per bale. And yet the people of the Dallas section, where there is no water competition, and in spite of their rate commission pay $3.00 a bale for 300 miles. You are not surprised to hear that they are imploring Congress to improve the Trinity river to Dallas at a cost of about $6,000,000, so they can have the benefits of competition by water transportation.

Now, if the Texas commission cannot do any better than that for its own people, in the name of common sense and right reason will the Inter-State Commerce Commission be able to do better by them? No, of course it will not.

What are the reasons for it? Why, there are very logical reasons. It costs the railroads of this country between $40,000 and $50,000 per mile to construct their lines. It costs them between $1,000 and $1,800 per mile, per annum for maintenance. Nearly all our waterways are the free gift of the Creator without a dollar's cost to any man, and though Uncle Sam is expected to improve them at a minimum cost, the burden falls on the whole nation, and it is not a tax on the commerce of the particular waterway improved. It costs the railroads fully five times as much to transport a ton of freight over the resisting substance of steel rails than it does to convey the same ton of freight on the water, which offers so little resistance. The burden then, I say, to the railroads is from $40,000

to $50,000 per mile original cost; the maintenance is from $1,000 to $1,800 per mile per annum; and the cost of propulsion five times as great as on the water. Do you wonder then, that the proposition I have stated is correct, that transportation on the water is only about one-sixth as high as that by rail?

Now what are we going to do about all this? Are we going to sit quietly by and let our railroads be developed as marvelously as they have been developed, until we are far ahead of the rest of the civilized world in this respect, while waterways improvements slumber? Germany, our great competitor, rarely ever has a train to carry more than 350 tons, yet on our western prairies you see train loads of 1,800 tons! Are we going to let the railroads develop forever and do nothing with our waterways? Are we going to let the powers of the old world,—away behind us in railroad development,—far outstrip us as they are now doing, in waterways development? For, you all know, that while we are ahead of them in railroads we are sadly behind them in waterways improvement. Every river in France and Germany has been so improved by canalization and otherwise, so many transverse canals have been constructed between them that it is said you can load a barge in practically every part of France or Germany and take it to every other part without breaking bulk, and the result thereof has been a wonderful cheapening of freight rates throughout those countries. Cannot we emulate the wise people of Europe in that respect at least?

I know we Americans think we are smarter than all the balance of the world, we think we lead the world in everything, but I tell you we are behind the world and badly so in waterway development. Let us wake up in this respect. Why, do you know, that as great a river as the Missouri,—actually navigable for 2,200 miles —for years and years, it has not had one boat load of freight between the city of St. Louis and Kansas City until about two weeks ago when a steamboat was loaded at St. Louis and went safely up to Kansas City. Can you conceive such a thing as that? That mighty river, the Missouri, absolutely neglected and forgotten until there is no freight on it at all.

Now let the friends of waterways get together. Let us rise in our might, from Maine around to the state of Washington, let us get together and demand from Congress a proper appropriation to carry on these improvements. It s a great cause we are striving for. It is meritorious in every way.

I sincerely hope that this society will take it up and advocate it; this engineering association which stands in the front rank of all that is good in the profession. You can do it, my friends. Put some of your ablest men to work on plans for better boats. I remember the boats that plied on our western rivers when I was a little boy, and they have the same old boats today, some of them actually worse than they were then. See the marvelous development that has gone on since you, Mr. Harvey, were on the great

lakes,—since you built that lock at "the Soo." See the truly wonderful development in all modes of transportation on the lakes in the last 25 years. Can one of you point to me a single improvement in river transportation in that time?

I made a suggestion to one of the great river associations the other day, to offer a $5,000 prize to the marine architect who would offer a design or a model of the best plan for an improved river boat, with improved methods of handling freight on our rivers. I sincerely hope it will be done. You gentlemen ought to encourage it. You ought to help build up the navigation on our rivers. It pays to encourage it and you should help it along. Help us spread the gospel of cheap water transportation with its marvelous benefits, and great will be the result.

*President Arnold*—Mr. Ransdell has very forcibly pointed out to us the importance of a comprehensive waterway system in this country. Let us hope that some definite results may soon begin to be realized.

We wish to hear now from the next speaker, a man who has carried out the most important work of its character in the country as Chief Engineer of the Sanitary District of Chicago.

*Mr. Isham Randolph,* M. W. S. E.—Tonight we have had an abundance of good things. We have heard from our own companion, a most interesting address and containing much useful knowledge on the subject of waterways. He has been followed by a patriarch, who has told us of what was first done to connect Lake Superior with the lower lakes. Following him we have heard that wonderful presentation of the cause of internal waterways.

Is not this enough for one evening? I cannot hope to come in as the dessert after such a feast. And so, I think the best thing that I can do is to ask you to take away with you the wonderful presentation which has been made here tonight and let that stick in your minds and let it be an incentive to you to help forward the great work which has been presented to you.

*President Arnold*—We would like to hear from Mr. John A. Fox, who is a member of the National Rivers and Harbors Congress.

*Mr. John A. Fox*—It is a pleasure to be identified as an engineer with this great growth which has been taking place throughout the country, and it is a rare reminiscence to look back to 1888 when the question of waterway developments in the United States was the only question before our people. It is perhaps familiar to some of you who have studied this question but as early as 1825 there were no less than 8,123 miles of waterways projected or under improvement by the United States. At that time the great improvement of the railroad was not known, but the inland waterways and the great system of canalization which we are now considering was contemplated and as early as 1830 there were not less than sixteen thousand miles of connecting canals to join the waterways of the United States.

Coming as they did, however, in 1845 to 1850, with a great deal of impetus and proving one of the sensations of the great drama of the development of our nation, the railroad came quickly to the front and occupied a paramount position; for economic reasons it has held that position until 211,000 miles of railroad now interlace our continent, built at a cost of more than thirteen millions of dollars.

With the present development of the railroad systems of our country, we now turn to the more economic question which we left off in 1830, and in a serious and economic spirit look again to the development and the perfection of our waterways. And so, we are simply taking up the work that has been left off for a short period and until the railroads had developed to their state of today.

I might mention incidentally that the part the waterways have played during this age of railways and during the great development of the drama of our nation has been so marked, that had it not been for the thousand mile link of waterways on the great lakes that has been spoken of heretofore, our advancement in the development of the great west and the interlocking of our magnificent country, the building of our cities would have been almost impossible. I state this and call your attention to it in this way: That the greatest iron producing country in the world is in the Mesaba Range on the western edge of Lake Superior; that the greatest coal producing fields of this country are situated in the land locked sections of Pennsylvania and Ohio. Had the iron and the coal which have made us what we are today, been separated by a thousand miles of land instead of being placed almost in juxtaposition by a thousand miles of water, it is difficult to realize what a handicap would have been placed upon us in the production of our steel rails or in the production of our great steel buildings.

Carrying out further the line that was suggested by Congressman Ramsdell, I will state this: as an example of why the development of the waterways would be profitable and within the scope of a reasonable expenditure of money, if all of the coal, iron and such heavy class materials as are termed the low class or raw materials, entering largely into the manufacturing world which were produced in 1903, had been carried an average distance of five hundred miles by water, or had been able to take advantage of a movement one way or the other of about five hundred miles, there would have been a saving to the producer and the consumer on all of these low class materials, (if only the rates per ton mile by rail had been reduced one mill), of $167,000,000. It would cost to improve the Ohio and the Missouri and the Mississippi, the greatest inland waterways in our nation, $155,000,000, yet the saving that would accrue from such an expenditure on simply the low class freight, as I have mentioned, would have amounted (on the production of 1903) to $167,000,000 and would amount to more annually each year. The difference today between the rates per

ton mile on the rivers and by the railroads is about half a cent or five mills per mile, so that if the entire difference had been taken, it would have been five times as great.

These figures, based upon statistics, show that if the United States body of law makers and developers of our waterways were business men and would consider the development of the waterways as a business proposition, as a board of directors looks upon the development of lines of railroad, they would not hesitate one moment to invest four hundred million dollars that are now necessary to develop our waterways, but would proceed at once to do so, knowing that they would pay for themselves almost, within three years.

While in St. Louis recently I had occasion to gather some statistics for the St. Louis people, to show what the saving would be on the freight moving between St. Louis and the Gulf if the waterway of the Mississippi River was so developed, at an expenditure of about fifty million dollars as to establish a permanent waterway at all seasons of the year, such as could be taken advantge of by cereals and coal and freights of that class, moving southward, and it proved that if the waterways had been such that the entire amount of freight could have been moved by the water route, the saving would have been nineteen million dollars a year on the average crop that was produced in 1903.

But, there was one reason, gentlemen, why I was so anxious to have this question brought before you, my brother engineers, and that is this: it is to the *engineer* that this great question comes home. The solution of the development of the waterways not only appeals to you from the great character of the work in canalizing and developing the rivers, but it also appeals to you in the devising of some means of mechanical applictaion, for the cheap handling of freight in bulk by the inland rivers, and therfore in the building up of commerce. It devolves upon you to devise an improved means for the loading and unloading of freight in bulk on the great rivers. The engineers have demonstrated this on the Great Lakes where science has reduced the great cost of labor between the Great Lakes and the places where the railroads have made such great strides; therefore I wish to call your attention to the great thoughts which have been brought out by our guest, Mr. Ransdell, and put them before you for application in your profession as an aim in looking forward to engineering engagements in the future. It opens to you a vast avenue, not only in the canalization of the rivers, not only in the reduction of the banks of these rivers and the building and construction of levees, but also, in the devising of some method whereby the freights may be more cheaply transferred by scientifically constructed boats for the inland waterways.

*Mr. Dowse*—I am able to testify to our friend's remarks about the "Soo Canal," because for thirty years my home was at Duluth and the whole future at that time depended upon its being the

chief place on Lake Superior where rail and water met. I had the privilege of going through that canal first, in May, 1870.

My first experience on the Great Lakes was to come to this port, from Collingwood, Canada, on a steamer of about three or four hundred tons, one of the *large* steamers at that time running on the lakes, I went into Lake Superior in May, 1870, en route to Duluth, my future home. I could see, as any man with comprehension or judgment could see, that the whole future of that town, in which I spent thirty ears of my life, was dependent upon its waterways.

Therefore, I have given this subject a great deal of attention, of time, and of thought, and have expended considerable money in attending different waterway conventions and in examining not only those of the United States, but those on the other side of the Atlantic.

I am simply one individual who has seen this city grow. I came here to reside in 1854, and the city then had a population of 36,000. Only two railroads then touched the east bank of the Mississippi, and none were west of it. I have seen Minneapolis and St. Paul grow from a nominal population of 4,000 and about 1,000 to a now combined population of nearly 600,000. I went to Duluth when the original forest stumps were freshly cut, and have seen it grow to the third port in the United States for its tonnage, and *done in a seven months' navigation.* I have seen those small steamers give way to mammoth boats which now ply the lakes. The one that I went on to Duluth in May, 1870, was a steamer of about eight hundred tons; and it was then one of the largest. When the New York Central R. R. built the India, and China and Japan of eleven hundred tons, we thought we had monsters. Yet, within the last thirty days there have been contracts let for the construction of eight steamers, six hundred feet long and carrying from ten to fourteen thousand tons. There are today running in the Lake Superior trade, forty-three steamers of five hundred feet long and over; more five hundred foot steamers than ply on the Atlantic. and now a contract is made for 10 large steamers, five of them 480 feet and five of them over 500 feet long, which will go into the Lake Superior trade through the "Soo Canal." This very week contracts have been closed for eight steamers 600 foot long and over. All these steamers are to run in the Lake Superior trade through the canal which Mr. Harvey first built, though since enlarged.

I have seen the growth of the "Soo" canal which was originally built with its two 9 foot lifts, to its present single 18 foot lift, and it is very gratifying to speak on these changes which occurred in my life, for I know that the question of cheap transportation is what has made this country habitable, and what has made possible the marvelous development of the great Northwest.

Now these are not all of the reasons that I could give; there are many others that waterways have made possible. They are deeply

interesting to the communities, to the sections and to the nation.

It seems to me, that there is one thing I have not noticed in your different publications which it has been my privilege to read, a point that has not been used in your arguments.

In times like these, when thinking men seem to see how the *individual* in almost everything, is sunk into a combine or trust, and men begin to realize that they are losing their individuality; when I make these statements of these great growths, I am only a witness of the past, but I say that you want to make one item that appeals to the individual. There is one point which it would seem to me well to mention, that you should draw the interest of the individual, particularly those connected with agriculture, because many of the members of Congress come from agricultural states. The agriculturist should be shown this item, because it comes directly to his individual interest. You take the general range of cereals, it would be safe to put it at twenty bushels to the acre, which would be small; for every penny saved per bushel in transportation he is gaining ten per cent on two dollars, if his crop averages twenty bushels to the acre and he saves twenty cents, his land is actually and positively gaining a value of two dollars an acre for every penny thus saved. This should be brought home in some way to the *individuals.*

Again, at Duluth, I have seen that port grow from three to four arrivals a week up to the third largest port, in point of tonnage, in the United States, and today there is no port on earth that approaches Duluth in the high tonnage average and the magnificence of the steamers that go into that town; yet thirty-six years ago when I went there first, Duluth had a population of five or six hundred. I know too, how the Duluth people had to labor to get Congress to make an appropriation for their harbor improvements.

It is twenty years since I have taken any kind of active interest in these matters. This is the first time since then when I have said anything on this subject, and you do not know, gentlemen, what great gratification it is to find a man in Congress who will stand up and talk and do as Mr. Ransdell has done. It is refreshing.

I have been over most of this country. I know the Mississippi and Missouri rivers from New Orleans to Fort Benton and up to St. Paul. I have been down in the lower river several times and I have been from St. Louis north many times.

Gentlemen, the improvement of the waterways of the United States is the work that should be taken up by the national government today; in fact it is the only money that this government spends for which it ever gets anything back. You may talk about your marvelous gold development down in southern Nevada, or you can talk about Mr. Morgan or the steel trust, or any particular kings of finance, but none of them can stand up and make a statement that bears any sort of comparison to what that gentleman, Hon. Joseph E. Ransdell, M. C., from Louisiana made here to-

night, and yet in the whole development of all our Great Lakes waterways, there has been expended only $70,000,000.

Now I have seen all these developments; I have seen this city grow from 36,000 to 2,000,000. When I came here in September, 1854, La Salle Street headed at Madison Street, and Madison Street was the southern limit of civilization. There was one street across the river (the south branch), and Madison Street for a couple of blocks, on the west side of the south branch was built up a little and then you could see sun-down if it had not been for the hills out on this side of the Desplaines river.

One does not have to go outside of the boundaries of just this one city to clearly evidence an object lesson of the first and most convincing class, to prove the profitable wisdom of the United States government policy of improving its magnificent internal waterways. One of the first appropriations for interior waterway improvement was its land grant for the building of the Illinois River and Lake Michigan Canal to the Chicago River, that made sure the foundation and up-building of this magnificent city of over 2,000,000 people on the boggy flat and mud hole that this city's site then was.

From my own knowledge, the Chicago river, below and above Clark Street bridge, is now a full third wider than its original width. In 1854, where the north and south branches came together was a large island, and vessels could not go above Madison Street bridge in the south branch; the north branch was not navigable for boats of any draft. In 1854 there were not a single cellar under any business building, in what was then the entire city of Chicago. The very highest place on what was then "Chicago Prairie" from the Lake Shore to the uplift just east of the Desplaines river was eight feet above lake level, and that, near the Lake Shore; it was much lower, back of that. I am told that the street surface of today, about the City Hall and Court House is 20 feet above the natural surface formation.

Still, such was the mighty influence of the internal waterway improvement by that little "four foot of water" canal from the Illinois to the Chicago River, that the worst natural town site on the entire chain of the Great Lakes, has become in about 50 years, the second metropolitan city in the entire United States.

So with the twin cities of St. Paul and Minneapolis, the former by being at what has been, the head of navigation of the Mississippi River and the latter by the immense water power furnished by the St. Anthony Falls, which were improved by the U. S. government. During the next year Minneapolis will become the real head of that river navigation, by the completion of the twin "meeker dams" and locks by the national government, at a cost of three or four million dollars.

As with Chicago and the "twin cities," so with Duluth. No port

on earth has as handsome a harbor entrance as is the "Duluth Canal," through Minnesota Point into its unmatched harbor.

Greater object lessons of national and individual benefit the "Soo Canal" and all these cities have and will continue to give and receive from the limitless and continued benefits of a national policy of internal waterway improvements, which, if continued into new sections will doubtless give similar manifold profit to our government and all our people. Hence every citizen of the United States should feel a direct personal interest in the most liberal governmental continuance of a profitable national policy, and evidence that personal interest by voting only for such members of Congress who will willingly and loyally encourage the government in carrying out the object of the National Waterway Congress.

In conclusion, I thank you for the great pleasure of meeting such able and loyal champions of this cause for which, years ago, I did what I could in a small way to plant and foster its earlier foundation.

# NOTES ON ROAD RESISTANCES.

C. H. HUDSON, M. W. S. E.

*Presented November 7, 1906.*

About the year 1840, General Morin, under the auspices of the French Government, made extensive experiments to determine the resistance to traction encountered by carriages of various kinds on different road surfaces then in common use. The investigation was primarily for use in improving military carriages and military roads in France.

Considering the appliances then at his command, General Morin's work was certainly most excellently done. His researches have become classical in that line. His experiments have been repeated and verified, but have not been surpassed in thoroughness, and his deductions and formula have come to be recognized as final on the subject.

But those experiments were made at a time when even the railroad trains on a few hundred miles of railroads then existing, went but fifteen or twenty miles per hour, at their best. The only power at the command of General Morin was the horse: the speeds at which his vehicles were drawn were limited to the "walk" and the "trot," and pneumatic tires had not then been invented. The first pneumatic tires were made shortly afterwards in England, but the invention was wholly forgotten for nearly forty years.

At the present time Automobiles are driven upwards of sixty miles per hour, pneumatic tires are in use everywhere, and it is more than likely that our modern roads are better than those which General Morin tested in 1840. We believe that further experiments at high speeds and with pneumatic tires are in order.

The dynamometer has frequently been used in making tests upon our railways, and was suggested as the proper instrument for use in this case: but former use of this instrument by the writer had not been altogether satisfactory. A committee of the "British Association of Automobilists" have been making some experiments with carefully designed dynamometers which tested one wheel at a time under different loads. The wheel to be tested is mounted on a frame drawn behind an automobile and attached thereto by a system of levers and springs. A pencil or point attached to the levers registers the tension on the spring, and another pencil registers the velocity, on a paper which is moved by clock work. The machine is complicated and delicate, and at best, tests but one wheel under unusual conditions. As an academic question, it is of course, desirable to know the road resistances as distinct from the resistance of

the air and of the axle, but practically the maker or purchaser of an automobile desires to know what power and gearing are required to run his automobile over the roads and grades where the car is to be used, and the tire maker wishes to demonstrate whether his tires or those of his competitor will carry a given automobile with less expenditure of power; moreover, the final result of the British Association experiments are not yet published, we believe.

To get some information on this subject and to get some idea of the road resistances at high speeds the writer made numerous tests, with different cars and over various roads, and upon these tests this paper is based.

The method of calculation adopted was somewhat similar to that used by General Morin to verify, or rather to illustrate the laws of falling bodies (see Ganot's Physics, sec. 79) but it is believed that this method has never before been applied to the measurement of road resistances.

The apparatus of General Morin to illustrate the laws of falling bodies, consisted of a frame holding a light vertical cylinder turned by clockwork on its axis. This cylinder was covered with cross-section paper. The falling body was a heavy weight carrying a pencil which was pressed against the paper by a light spring. The weight being dropped while the cylinder was in motion caused the pencil point to trace on the paper a curve from which the laws of the fall were deduced. The body might have been thrown upwards instead of being dropped, and in that case it would gradually *lose* its momentum and velocity owing to the *retarding* force of gravitation. It would come to a rest, then gather new velocity and momentum under the influence of the same gravitation (now an accelerating force) and reach the starting point with practically the same momentum and velocity with which it was thrown upwards. The two portions of the curve traced on the cylinder would be parts of one and the same parabola. Either part might be examined mathematically with the same results.

The resistance which we desire to measure cannot be used to set our automobile in motion, as gravity sets the falling body in motion, but it can bring it to rest just as gravity brings to rest the weight projected upwards, and the effect of resistance as such retarding force can be accurately observed and registered. The loss of momentum will be the measure of the retarding force.

The attraction of gravitation is said to be "32.16 feet per second" at the earth's surface: this means that it is sufficient to overcome the inertia of the mass, and impart to it, or take from it, as the case may be, a velocity of 32.16 feet in one second. If we should find that the road resistance was sufficient to take away from our automobile a velocity of 32.16 feet in one second we would know that the road resistance was equal to the attraction of gravitation

for the mass of our automobile, or 100% of the weight. If the road resistance retarded the automobile only 3.2 feet in one second we would know that the retarding force was 10% of the weight. Such resistances are conveniently expressed as percentage of the mass or weight, or in pounds per ton.

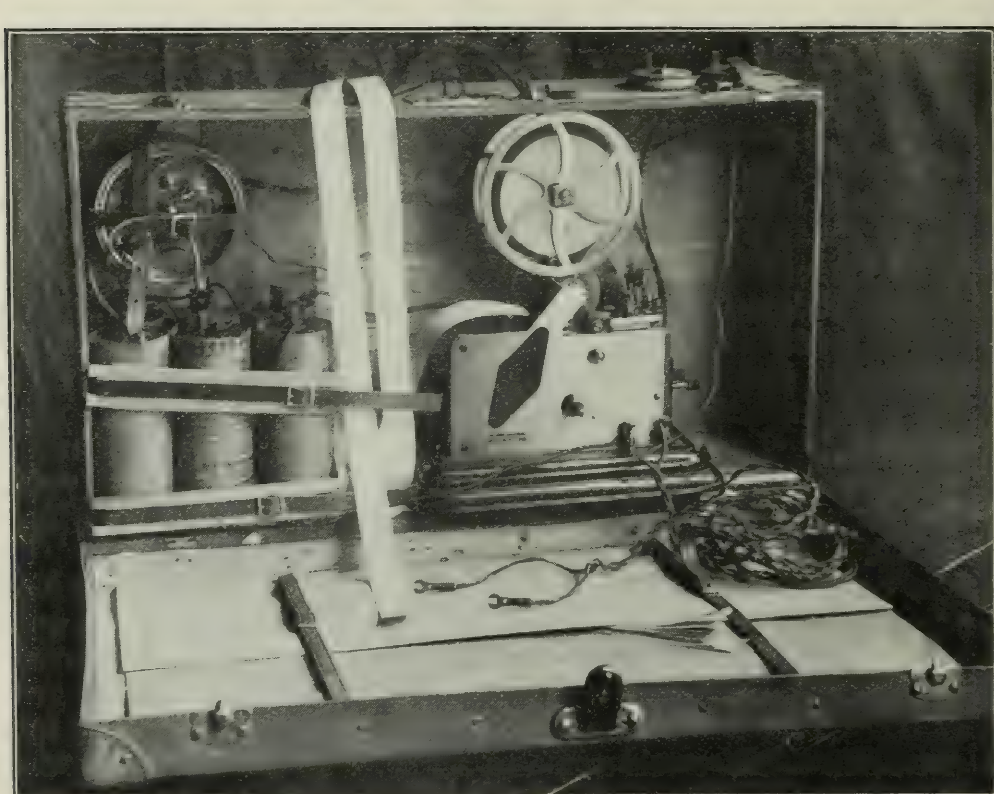


Fig. 1.

That, in brief, is the method to be described. After the automobile has been set in rapid motion, preferably on a level road, it is allowed to come to rest under the influence of its own momentum and the road resistance alone. The velocity is registered automatically and as a loss of velocity means a proportional loss of momentum, the retarding force or resistance, causing that loss of velocity can be readily calculated.

RECORDING INSTRUMENT.

The recording instrument consists of a telegraph register, such as is in common use to register calls for messengers, and fire alarm calls. It has two pencils or points operated by electro-magnets, and registering dots, dashes and spaces on the paper tape unrolled by clock work. The magnets are operated by different circuits, but the points leaving their impressions on the same tape, in parallel

lines. A *three* circuit instrument is made, and would have been better, for reasons which are hereafter explained, but was not available at the time these tests were made.

One of the circuits is connected with a clock, and the corresponding pencil registers half seconds. The other magnet and circuit is connected with a contact point at the wheel of the automobile, and the corresponding pencil registers half revolutions of the wheel.

*The Clock.* One of the clock wheels revolves once in sixty seconds, and has sixty teeth. It is the wheel that carries the second hand. A small insulated brass spring is so placed that each tooth of the wheel makes an electric contact with the spring as it passes, thereby operating the time pencil on the telegraph register. The circuit is closed one half of each second, and open the other half; so the dashes, and the spaces on the tape, each represent a half second.

*The Axle Connection.* The contact at the axle is operated by a cam fitting over the inner part of the hub of the wheel, and held in place by a metal strap tightened by a screw. The cam covers half the circumference of the hub, thus closing the electric circuit during one half of each revolution of the wheel. A flat spring held near the cam by a small piece of board, strapped to the axle or spring of the automobile forms the "contact," and the two parts, cam and board, are the only attachments in any way fastened to the automobile. Not an additional bolt or screw is required, and not a scratch on the paint of hub or spring is necessary.

*Case.* The telegraph register, batteries, (two of three dry cells each,) clock, and roll of paper are all placed in a common suit case, so as to attract as little attention as possible. The connections at the axle are made with a flexible lamp cord which is gathered up into the spare space in the suit case when not in use. See Fig. 1.

The entire apparatus is carried on the seat by the side of the operator, or on the floor between his feet; or it may be carried in the tonneau under the care of an assistant. Two switches of easy access, on the top of the suit case, serve to close the two circuits when the tape is about to be taken. The telegraph register stops automatically when the circuits are both permanently opened.

A third switch is also upon the case, so arranged that when it is closed it will open the wheel circuit if the wheel circuit is closed by the cam, and will also close the same circuit if the circuit is open at the cam. The object of this is explained later, as enabling you to mark more positively the point at which the car ceases to move, by marking upon the tape a series of short marks and spaces.

OPERATION.

*Disconnecting Engine.* As the main object in view is to measure the loss of momentum when the automobile in under the influence

of road resistance alone, the engine must be disconnected during the time that the record is being made. It is used merely for the purpose of imparting the momentum to the car in the first instance.

The car first used was an Eldridge runabout, having a friction disc clutch and sliding gear transmission. At high gear froward, the engine was direct conected with the driving shaft, and no gears were in mesh. The direct connection could be broken by bringing the reverse lever to a neutral position, leaving all the gears idle. This was found to be more rapid and positive in disconnecting the engine from the driving wheels than merely releasing the friction clutch. The Eldridge had 30 by 3 in. wheels.

Other tests were made with a Jackson automobile; the transmission was planetary, and the engine was disconnected by releasing the clutch which coupled the engine directly with the driving shaft. This car had a canopy top, and 30 by 3½ in. wheels.

Other experiments were made with a large four cylinder car made by the Woods Co., of Chicago. This car had 36 by 4½ in. wheels, Mechelin tires, double chain drive, and cone clutch between the engine and transmission. As affecting the wind resistance it should be said that the body was of the enclosed or limosene type, with a glass dash in front of the driver's seat.

*Modus Operandi.* But one operator is required to manage the automobile and record the data, though it is a little easier if the labor is divided between two.

The following are the several steps of the experiment.

*First.* Start the automobile at full speed along the road to be tested.

*Second.* When fairly going at full speed, close the two switches, whereupon the telegraph register will commence to record the half seconds of time, and the revolutions of the wheel.

*Third.* Suddenly disconnect the engine from the transmission and also, (but afterwards) open the sparking circuit and stop the engine, to prevent its racing. For this purpose we had a switch at the side of the operator's seat.

*Fourth.* Do nothing more until the moment the car comes to a full stop; at that exact moment open and close the wheel circuit rapidly a few times. For this purpose is the third switch before mentioned.

*Fifth.* Open all the circuits, at the switches, whereupon the telegraph register will automatically cease unrolling the tape.

*Sixth.* Remove the tape upon which the records have been made, fold it up, indorsing upon it the date, number, direction, place of experiment with such other data as are desired, as the direction of wind, or grade, and put it in the pocket to be studied at home.

*Seventh.* Run back over the same road, but in opposite direction to eliminate by comparison any irregularities caused by grade or wind.

The beginning and end of a sample tape designated as "No. 8" made by the large car are shown in Fig. 2.

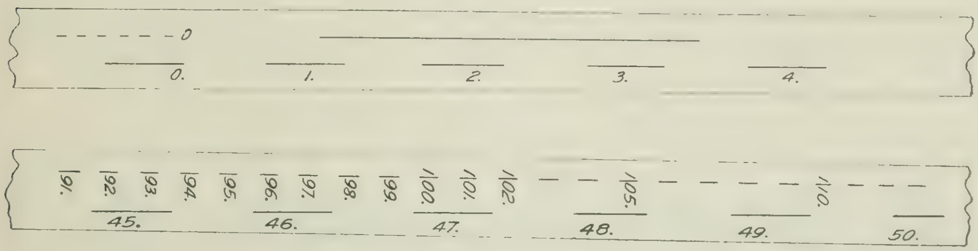


FIG. 2.

The lower lines of dashes are made by the clock pencil, and the upper line by the wheel pencil. The short dots, at the zero point, were made by the operator by means of the third switch, to indicate the exact point or moment of coming to a complete stop.

If there had been a third circuit and third pencil point as has been suggested, it would have been used to indicate the final stop, and also other points of interest that we might desire to register, as street crossings, or "bumps," corners, or other point of interest, but the plan used answered the purpose very well, for the short dots are so very different from the last few dashes of the wheel, that there is no possibility of mistaking one for the other.

This third switch was so arranged that if the car came to a stop with the point making a dash, the switch would *open* the circuit a few times rapidly; while if the car stopped on a "space," the same switch rapidly *closed* the circuit a few times. Inasmuch as the car itself required no attention from the operator at the moment of stopping, he could give his entire attention to this special switch. It is rather important that this point when the car comes to a rest should be accurately marked, as all calculations afterwards made start from that point as zero.

The whole experiment is over in two minutes, and may be repeated back and forth over the same road as often as may be deemed necessary in order to arrive at a proper average. Or the apparatus may be transferred to another automobile, if the object is to compare different machines, or machines with different tires.

*Platting the Lines.* At the office the various tapes are examined, the revolutions and seconds counted and numbered and either tabulated or platted on cross section paper, or both. If tabulated the averages of a number of runs over the same road can be made, and this average used in our calculations. If platted on cross section paper the points representing corresponding "time" and "distance" form a curve showing the relation between time and distance from the highest to the lowest speed of the car. This curve is the result of observation and experiment, and not of any preconceived notion as to what the relation is or should be.

In Fig. 3 is shown the tabulated values of distance (D) and time

(t) taken from one of the tapes, a portion of which is shown in Fig. 2 and also the curve obtained by platting them. It is a typical curve, and obtained with the big automobile; we will use it to illustrate the method of calculating resistance, though in practice it was thought advisable to take the averages of several runs back and forth over the same road.

DISTANCE CURVE

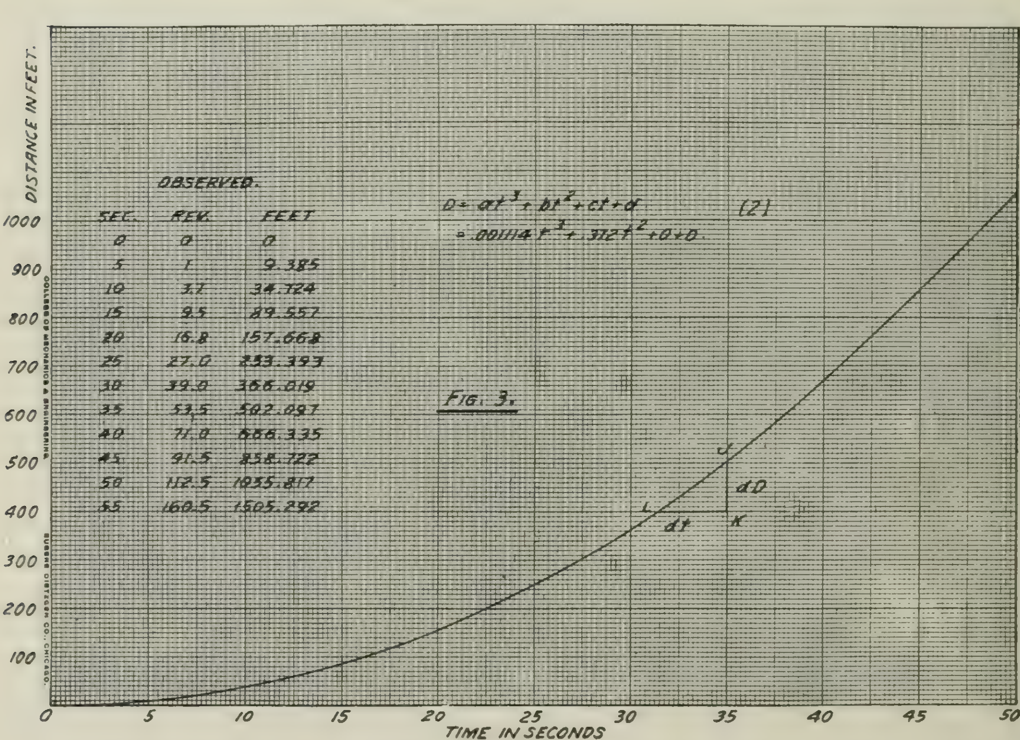



Fig. 3.

The distance moved each revolution of the wheel was accurately measured upon the ground, by laying down a tape line, and letting the wheel make a revolution by its side, marking the wheel so as to be sure of the exact revolution. We did not rely upon calculations from the diameter of wheel nor even upon measurement of the wheel while at rest.

The curve here shown has the general appearance of a parabola, such as would correctly show the relation between time and distance in the case of a falling body; but a careful examination disclosed that it departs from the parabola more and more as the distance from the origin increases, indicating that the resistance increases with the increase of velocity. In the case of falling bodies we know that the accelerating force, (resistance in our case) (g) at any point on the earth's surface is constant. This can hardly be the case with road resistance and the departure from the parabola was not unexpected. It, however, remains to be determined accurately just what is the amount of this departure.

The equation of a parabola tangent at its origin, is of the second degree, and of the form

$$D = bt^2 \qquad (1)$$

Our curve must be of the third degree, (or higher), included in the following general form,

$$D = at^3 + bt^2 + ct + d \qquad (2)$$

In practice we find that the curve of the third degree approximates very closely to our observed curve. At velocities of a hundred miles per hour or more, there may be an appreciable variation from the curve of the third degree, but at speeds within our reach at the present time, the third degree equation and curve are entirely sufficient to represent the relation with complete accuracy.

Indeed, the scale of Fig. 3 is entirely too small to show any difference between the observed curve and the locus of the third degree equation, calculated as hereafter shown.

The numerical values of the co-efficients a, b, c and d might be calculated directly and in the first instance, but it is more convenient to retain the literal co-efficients for the present.

Examining a small portion of the observed curve, as J-L we see that $\frac{JK}{KL}$ is the ratio between distance and time. It is the velocity (V) at that point. The numerical value is derived from equation (2), and in the language of differential calculus is as follows:

$$V = \frac{dD}{dt} = 3at^2 + 2bt + c \qquad (3)$$

VELOCITY CURVE

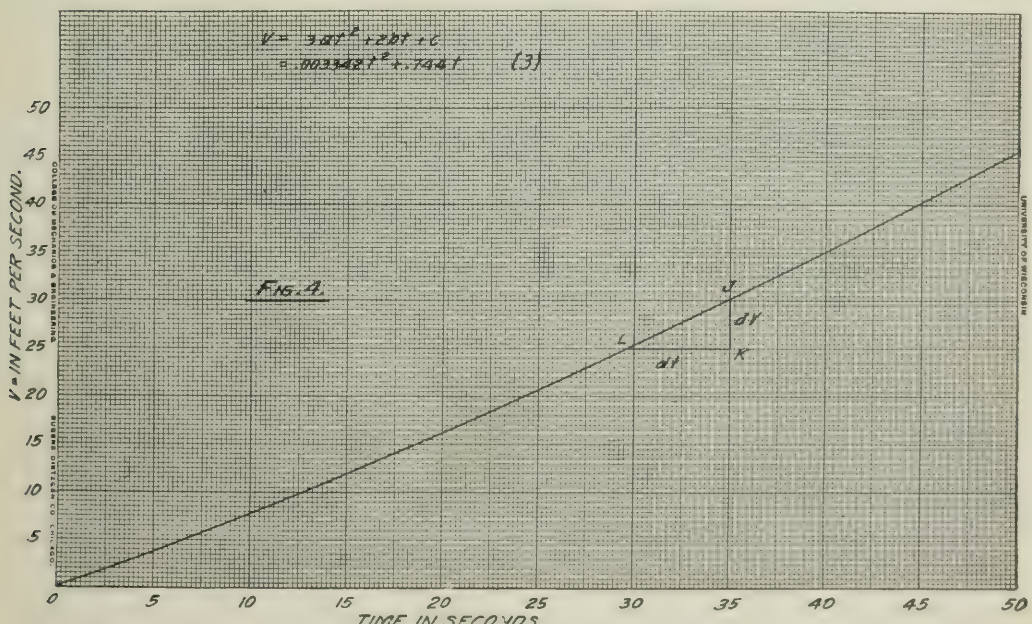



Fig 4

The locus of the equation is shown in Fig. 4. This curve shows the velocity in feet per second at each point of time during the test.

An examination of any small portion of this curve for changes in velocity, as we examined (2) for changes in distance, shows that this change "r" is represented by

$$r = \frac{dV}{dt} = 6at + 2b \tag{4}$$

This change in velocity is caused by the resistance we desire to measure, *i. e.*, the resistance of the road, the air, and the axles or internal resistance of the machine. It is a loss of velocity in feet-per-second, just as the force of gravity is said to be 32.16 ft. per sec. To compare our resistance with the force of gravity (or weight of the automobile) we must divide by 32.16, thus,

$$R = \frac{rW}{g} = \frac{W\ (6at + 2b\ )}{32.16} \tag{5}$$

Equation (5) gives us values of R, but not in form for convenient use, as it gives it in terms of time, while we desire it in terms of velocity, or V.

This value may be obtained by solving the quadratic equation (3) as follows:

$$\text{From (3)}\ V - c = 3at^2 + 2bt \tag{6}$$

$$\frac{V-c}{3a} = t^2 + \frac{2b}{3a}t \tag{7}$$

$$\text{Completing square}\ \frac{V-c}{3a} + \frac{b^2}{9a^2} = t^2 + \frac{2b}{3a} + \left(\frac{b}{3a}\right)^2 \tag{8}$$

$$\text{Whence}\quad \sqrt{\frac{V-c}{3a} + \frac{b^2}{9a^2}} - \frac{b}{3a} = t \tag{9}$$

Substituting this value of t in equation (4) we have

$$r = 6a\left\{\sqrt{\frac{V-c}{3a} + \frac{b^2}{9a^2}} - \frac{b}{3a}\right\} + 2b \tag{10}$$

$$= 2\sqrt{3a\,(V-c) + b^2} \tag{11}$$

$$\text{and}\ R = \frac{2W}{32.16} \times \sqrt{3a\ (V-c) + b^2} \tag{12}$$

But when $t = 0$, D and V are both 0 since at the stopping point the car has no velocity and the distance is also zero and equation (2) becomes

$$D\ (= 0) = 0 + 0 + 0 + d \tag{13}$$

$$\text{whence}\ d = 0 \tag{14}$$

$$\text{(3) becomes}\ V\ (= 0) = 0 + 0 + c \tag{15}$$

$$\text{whence } c = 0 \tag{16}$$

and (12) becomes

$$R = \frac{W}{16.08} \times \sqrt{3aV + b^2} \tag{17}$$

This is the final formula for R. It is calculated once for all and nothing remains but to determine the numerical values of the constant coefficients, a and b, for each new experiment.

In this formula, V is velocity in ft. per sec., and R is in pounds or tons—the same unit as weight W.

With c and d = zero, there remain but two of our coefficients in equation (2) to be determined, viz, a and b. For this purpose two of the values of t, and the corresponding observed values of D are substituted in equation (2). We will use t = 20 sec. and = 40 sec. Then (2) becomes

$$
\begin{array}{lrcll}
 & 8000a + 400b + 0 + 0 & = & 157.668 & (18) \\
 & 64000a + 1600b + 0 + 0 & = & 666.335 & (19) \\
(18) \times 4 & 32000a + 1600b & = & 630.672 & \\
\hline
 & 32000a & = & 35.663 & (20) \\
 & a = .001114 \text{ and } b & = & .372 & (21)\ (22)
\end{array}
$$

Substituting these values in equation (17), and we have

$$R = \frac{W}{16.08} \times \sqrt{.00334V + .13838} \tag{23}$$

which gives the values of R for this particular curve.

We may transform this into the following,

$$R = W \times \sqrt{\frac{V + 41.43}{278.2}} \tag{24}$$

which is very convenient form for slide rule calculation.

This gives the resistance as a percentage of the weight at any velocity in ft. per sec. if we omit W.

Equation (17) is deduced once for all, and for any new test the only calculations required after counting the revolutions for 20 seconds and 40 seconds, are the solutions of the equations corresponding with (18) and (19); merely a solution for the two unknown quantities a and b, and substituting their values in (17).

The locus of equation (24) appears in Fig. 5, and shows the resistance to traction of the car at various velocities: The scale at the left being in percentage of the weight, and that at the right in pounds per ton. The scale at the bottom is in feet per second, and that at the top in miles per hour.

To show the complete analogy to the laws of falling bodies, compare formulas. They will be recognized instantly: but note how one is derived from the other by differentiation:

$$D = 16.08t^2 \qquad \text{compare with (2)}$$

$$V = \frac{dD}{dt} = 32.16t \qquad \text{" \quad " (3)}$$

$$r = \frac{dV}{dt} = 32.16 = g \qquad \text{" \quad " (4)}$$

A careful inspection of several tape records, led us to suspect that possibly there might be some irregularity in the "distance," "velocity" and "resistance" curves just as the car came to a full stop; that the velocity did not, at the last, decrease with regularity to zero, but that the final stop was somewhat sudden. Indeed in a railroad train, or upon a street car, one frequently experiences an unpleasant jar at the exact moment of stopping; and the converse has sometimes been noticed; viz. that it required a greater effort to start a vehicle into motion, than to keep it moving when once started.

RESISTANCE CURVE

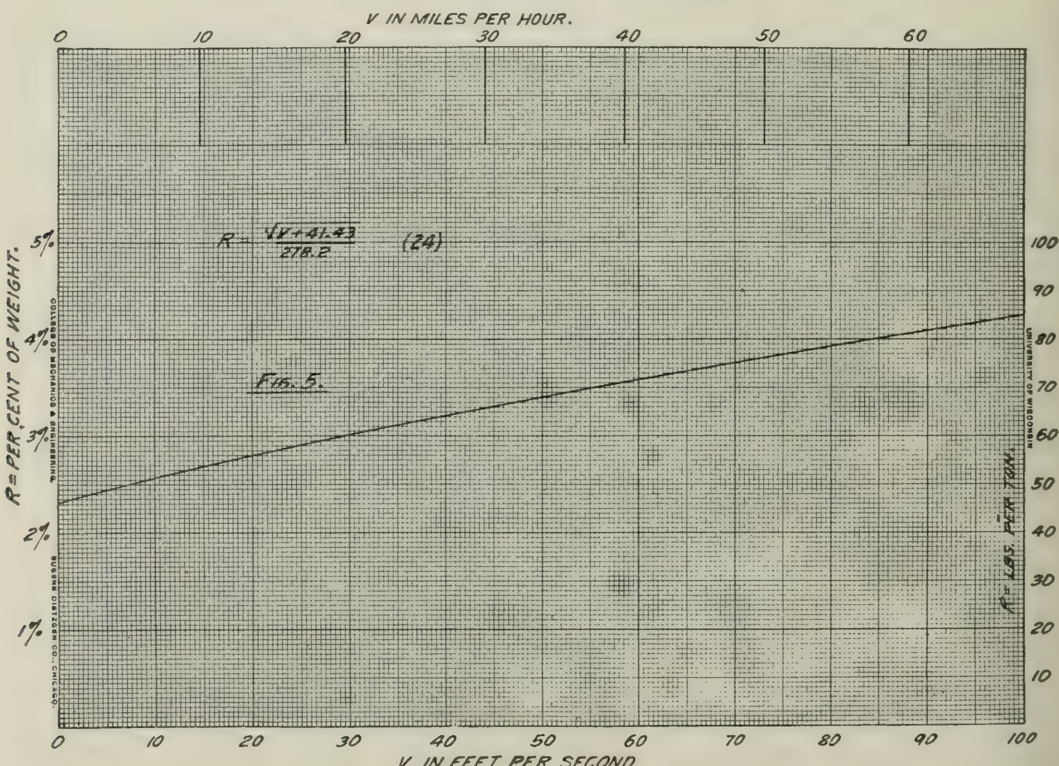



FIG. 5

In order to determine this matter we examined with care, the distance curve at four several points *not* including the origin, and *without* assuming that the curve was tangent at the origin or that the velocity V, was zero at that point. In other words, we did not assume that c and d were zero, nor that our origin correctly represented the exact point in time and space where the car stopped.

The computation became a little more complicated. We were obliged to solve four, instead of two equations, to determine the

four coefficients a, b, c, and d, and the final formula, (instead of (17) ) becomes

$$R = \frac{W}{16.08} \sqrt{3a(v - c) + b^2}$$

Examined this way we find the equation of a curve passing through four points of our observed curve, *not* including the origin.

Upon examining the same tape "No. 8" in this manner we find the following values for a, b, c, and d:

$$a = 0.000313 \qquad c = -0.4066$$
$$b = 0.41606 \qquad d = -3.128$$

These coefficients differ considerably from those obtained when we assumed that c and d were zero, but they combined in such a manner that the *numerical* values of R (resistance) vary but slightly from those we got before.

The values of R are so nearly the same as those we obtained assuming that c and d are zero, that we concluded that there was no substantial irregularity in the motion of the car at the stopping point, and that unless there was some unusual obstruction encountered by the car just as it came to a stop, there was no reason to believe that the character or amount of the resistance to be measured changed irregularly at the stopping point.

In certain experiments made on a down grade, however, where the car was started and allowed to run down hill, (instead of being started on a level and being allowed to come to a stop) we found that it was difficult to register accurately the exact time of starting. The slightest irregularity in the surface of the road would distort our "distance curve" near the origin. In the experiments on grades therefore, we solved four equations for the four coefficients a, b, c, and d (Equation (2) ), and did not rely upon the accuracy of record just at the zero point.

*Accuracy of the Method.* It is believed that the results obtained by this method will compare in accuracy favorably with those obtained by the use of any dynamometer. The only thing to be "adjusted" is the clock, and the only measurement taken is the circumference of the wheel. If the clock gains or loses as much as 1 1-3 minutes per day, the resulting error in our calculations will not exceed 1-1000, or one tenth of one per cent. of the total results obtained. The clock can easily be regulated much closer than that.

The circumference of the wheel might be calculated by using the formula for the circumference of a circle from its diameter, but instead of doing that, we measured the actual distance travelled in one revolution. A tape line was laid down next to the wheel track, and a pencil mark made upon the tire, then moving one or more revolutions of the wheel, enabled us to get a very accurate measurement.

Next, there is a possible error in determining the exact zero point, that is the exact point where the car comes to a stop. The half seconds are plainly marked, and the eighth-seconds can be easily and closely calculated, so that the possible error will be at most, a small fraction of a half second.

If extreme accuracy is desired, an allowance should be made for the momentum of rotation of the wheels; a rotating wheel, in such cases, has a slightly greater momentum to be overcome, than that due to its motion in a horizontal direction. The effect of this is confined to the wheels alone—a small portion of the whole weight moved, and it is hardly enough to overcome the resistance of the moving chain. The one may be offset against the other, and both ignored.

All the rest of the calculation is rigidly accurate. One has merely to count one, two, three, till the marks on the tape are all counted; the constant factors introduced are known to the fourth and fifth decimal point, if that were required; and the taking of the first and second differential co-efficients is rigidly accurate.

*Advantages of the Method.* As already stated, the accuracy of the results does not depend on any fine adjustments; no springs are required to measure the amount of the draught. The resistances are not overcome by any spring (requiring adjustment) but by the inertia of the carriage itself. This is fixed and definite and cannot get out of adjustment. As we desire percentages, and not the actual draught in pounds, we do not even have to weigh our car. No expensive dynamometer is required. The experiments do not attract undesired attention from bystanders.

The entire set of resistances from the highest to the lowest speeds are determined by one experiment, instead of the numerous separate tests which would be necessary if a dynamometer was used. And last, but not least, the tests measure the actual resistances under working conditions, and not under conditions that are unusual or imaginary and never realized in practice.

While it was found that the simpler and probably more accurate method of testing this road resistance with self propelled vehicles was that adopted upon level roads, other vehicles, not self propelled might easily be tested by a run down hill, if some means could be provided for properly steering them. The vehicle in effect is its own dynamometer. The road resistance is pitted against the inertia, and is stated and calculated in terms of inertia, instead of being measured by the spring of the ordinary dynamometer.

To apply this work practically, we will take some records of runs made with the "Eldridge Runabout," before described, upon a level road in good condition. The road lay east and west, and our runs were made first one way, and then the other, over the same ground, thus counteracting any slight difference there might be in grade, and any wind action at the same time.

As described, we acquired a reasonable speed with our car,

then cutting off the power, let it drift to a stand still. Such wind as there was, was very light, and blew at right angles to our course so that its effect could be ignored.

The observed distances for a number of runs, figured out at each five seconds of time, were averaged, the result of such average being as follows:

| | |
|---|---|
| At 5 seconds, distance = | 7.2 feet. |
| 10 | 25 |
| 15 | 58. |
| 20 | 103.5 |
| 25 | 170. |
| 30 | 248. |
| 35 | 350.5 |
| 40 | 469. |
| 45 | 605. |
| 50 | 757. |
| 54 | 880. |

To get the values of our coefficients a and b, we will use the equations for the distances at 10 and 50 seconds of time;

Without going through all the figures, our values found were $a = .00136$, and $b = .2347$;

Substituting these in our general equation, (17)

$$R = \frac{W}{16.08}\sqrt{3a\,(V - c) + b^2}, \text{ we have}$$

$$R = \frac{W}{16.08}\sqrt{.00408V + .055}\,; \text{ or omitting W or making}$$

W equal to unity (see discussion pages 682-683), and calling "R" a percentage,

$$R = \sqrt{\frac{V + 13.4}{251}} \qquad (25)$$

from which we get values (by slide rule) for R at various velocities, as follows:

| | |
|---|---|
| If V = 0, R (omitting W) = | .0146 |
| 5 | .0171 |
| 10 | .0192 |
| 20 | .0231 |
| 30 | .0262 |
| 40 | .0291 |
| 50 | .0318 |

This curve is shown on No. 6.

We give also the results from another lot of runs, made with the large Woods car, also upon a level road, with little or no wind, everything being worked in the same manner as with the Eldridge car.

As before, the distances were figured out for each five seconds and are averaged as before, and the results are given below:

RESISTANCE AT VARIOUS VELOCITIES

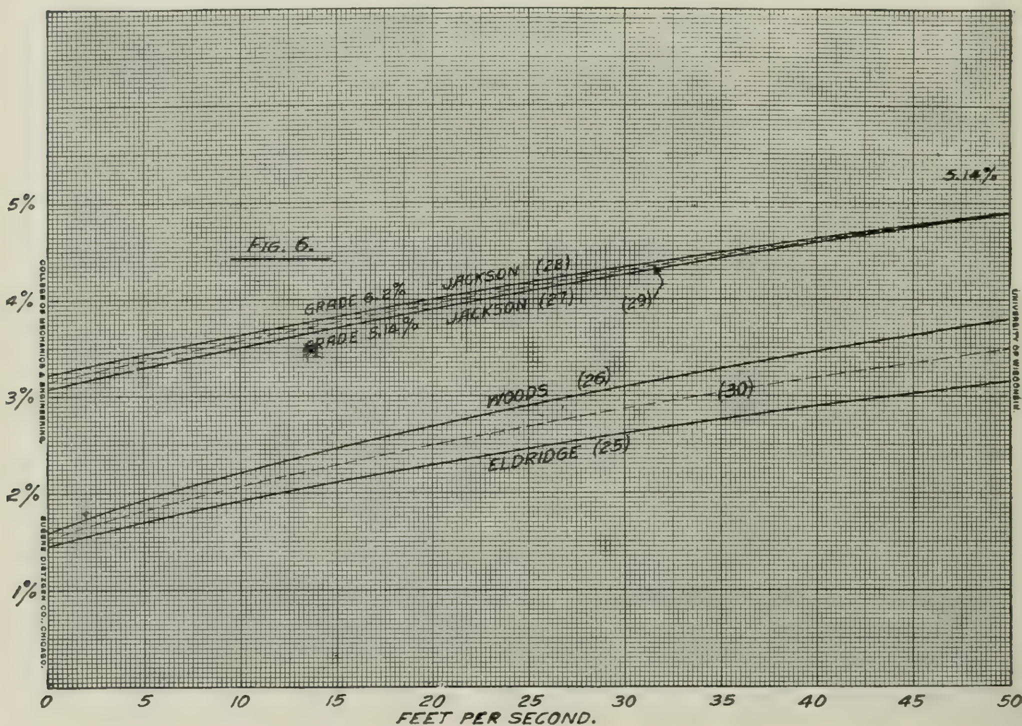



Fig. 6.

| | |
|---|---|
| At 5 seconds, distance = | 9.65 feet. |
| 10 | 32.84 |
| 15 | 72.92 |
| 20 | 130.62 |
| 25 | 211.1 |
| 30 | 302.8 |
| 35 | 418.8 |
| 40 | 554.6 |
| 45 | 734.7 |
| 50 | 928.2 |

We obtain the values of our coefficients in same way as before, and get

$$R = \sqrt{\frac{V + 10.45}{204}} \qquad (26)$$

from which the values of R are obtained, and are as follows:

| | |
|---|---|
| If V = 0, | R (omitting W) = .0158 |
| 10 | .0221 |
| 20 | .0270 |
| 30 | .0311 |
| 40 | .0349 |
| 50 | .0380 |

This curve is also plotted, see Fig. 6, and it will be noted is very nearly parallel to the curve from the Eldridge runs, though a little higher.

The roads upon which the above mentioned runs were made were very much alike, level, straight, smooth, though the one on which the Eldrige was run, was a trifle freer from surface sand than was the other. Probably an average of these two results would be a fair showing for that class of road.

In considering the runs down a grade we have conditions varying from those where the runs are upon a level and the car comes to a stop under the influence of the resistances of the road.

We have in the case of the run down the grade, first, the force of gravity, which starts the car from its stand, and tends to accelerate its motion as it goes down the hill; second, we have the resistances, which tend to retard the motion of the car, the one force acting against the other.

DISTANCE CURVES

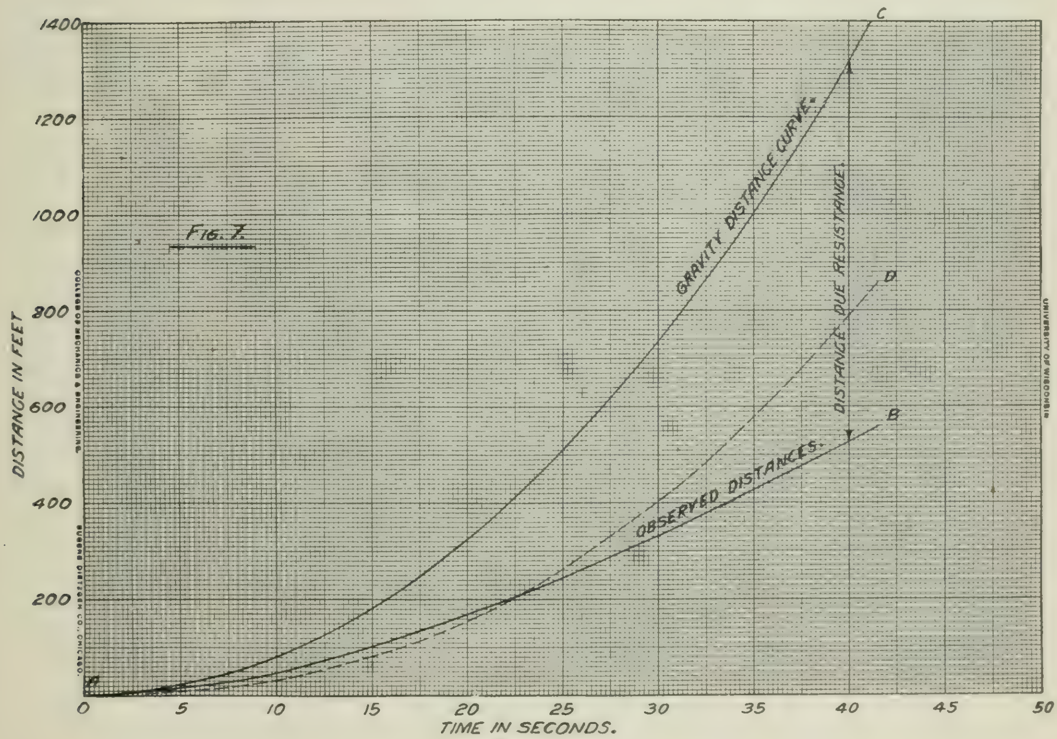



Fig. 7.

We know the force of gravity, and can figure out just what distance the car should run in any given period of time, if the force of gravity alone was in effect down a known grade.

We know from our observations, just what movement our car does make in such period. The difference between that and what the car would go under the influence of gravity alone, would be the effect of the resistance, and it is this which we wish to measure.

We made a number of runs down a 5.14% grade, letting the car start itself under the influence of gravity, and run freely down the hill. The observed distances were averaged, as in other cases,

the curve resulting from such average being plotted as shown, Fig. 7, and indicated by the letters A B. The scale of this sheet upon the bottom is seconds of time; the scale upon the left is in feet, and represents the distance moved in the elapsed time.

The line A C upon the same sheet, represents the curve of distance if gravity alone affected the car. The difference between these two lines represents the distance due to the effect of the resistance or the difference between the actual and the theoretical distances of the moving car. This curve is also shown in Fig. 7, and marked A D.

The equation for the curve of a falling body is $D = 16.08t^2$, which gives a curve of the second degree, and is a parabola. As our grade is 5.14%, we must take that percent of the equation for a falling body, to get our true distance.

and $D_g$ becomes $0.0514 \times 16.08t^2$ or $0.8265t^2$

To obtain the distances or curve which we wish to consider, we must subtract our observed distances from the theoretical gravity distance. The table below shows the three sets of distances for the average of these runs:

| Distance Due Gravity $D_g$ Feet | Observed Distance $D_o$ Feet | Distance Due Resistance $D_r$ Feet | Time Sec. |
|---|---|---|---|
| 20.86 | 13.5 | 7.36 | 5 |
| 82.65 | 47.2 | 35.45 | 10 |
| 186.96 | 101.3 | 85.66 | 15 |
| 330.60 | 171. | 159.6 | 20 |
| 516.56 | 249. | 267.56 | 25 |
| 743.86 | 336. | 407.86 | 30 |
| 1012.46 | 427. | 585.46 | 35 |
| 1322.40 | 527. | 795.40 | 40 |

To get the values of the constants we use the equations with the distances at 10, 20, 30, and 40, seconds.

The result finally obtained is

$$R = W \sqrt{\frac{V + 32.3}{184.4}} \qquad (27)$$

Our values of R at various velocities are shown below:

| If V = | R (omitting W) = |
|---|---|
| 0 | .0308 |
| 5 | .0330 |
| 10 | .0352 |
| 20 | .0390 |
| 30 | .0428 |
| 40 | .0461 |
| 50 | .0491 |

This curve is platted in diagram Fig. 6 together with those of the "Eldridge" and "Woods" runs upon a level.

This road was somewhat washed and much inferior to those upon which the level runs were made.

It may be noted that as the road resistance R approaches in amount the accelerating force due to the grade, (5.14%) (Fig-6) the observed distance curve, more and more resembles a straight line, as at B, Fig.-7. This is to be expected, for when the road resistance equals in amount the force of gravity the car cannot increase its velocity any more, but will proceed at the constant velocity indefinitely. A sketch of the observed velocity curve, similar to that in Fig.-4, would show a horizontal straight line at this part of the locus.

In order to check the results of these runs down a grade, others were made in precisely the same manner. One lot down a grade of 6.2% was averaged, and the figures of the averages are given below.

The first column gives the periods of time; the second, the observed distances run; the third the theoretical gravity distances, and the fourth the difference between the two, which are the distances due resistance. See Fig. 8,

| Time Sec. | Observed $D_o$ Feet | Gravity $D_g$ Feet | Resistance $D_r$ Feet |
|---|---|---|---|
| 5 | 15.65 | 24.92 | 9.27 |
| 10 | 53.00 | 99.70 | 46.70 |
| 15 | 107.88 | 224.31 | 116.43 |
| 20 | 182.01 | 398.78 | 216.77 |
| 25 | 276.93 | 623.10 | 346.17 |
| 30 | 385.32 | 897.26 | 511.94 |

Using the figures of 15, 20, 25 and 30 seconds to calculate the coefficients, we get, without here showing the details,

$R = \frac{W\sqrt{V+27.8}}{191.}$ (28) for our resistances, which work out as follows:

| | |
|---|---|
| If V = 0, R (omitting W) = | .0322 |
| 5 | .0342 |
| 10 | .0362 |
| 20 | .0398 |
| 30 | .0434 |
| 40 | .0467 |
| 50 | .0490 |

This curve is platted upon the same sheet as the other, Fig. 6 and it will be noticed that it follows that down the 5,14% grade very closely. The surface of the road upon the two grades was substantially the same, and there was no wind in either case.

The runs upon these two grades were made with the "Jackson" car.

These resistance values should be averaged before attempting to compare them with those deduced from the level runs. Such average gives the following values. See Fig 6.

| | | |
|---|---|---|
| If V = | 0, R (omitting W) = | .0315 |
| | 10 | .0357 |
| | 20 | .0394 |
| | 30 | .0431 |
| | 40 | .0464 |
| | 50 | .0493 |

and our equation becomes

$$R = \frac{W}{16.08} \times \sqrt{.00751V + .257} = W\sqrt{\frac{V + 35.16}{186.05}} \quad (29)$$

As before explained, this car had a "planetary" transmission, and was arranged so that when "drifting", or running of its own impetus, the gears were in mesh, and moved by the chain, though when working in high gear, the sleeve carrying the sprocket wheel was clamped to the engine shaft, and no gears were in motion.

## DISTANCE CURVES.

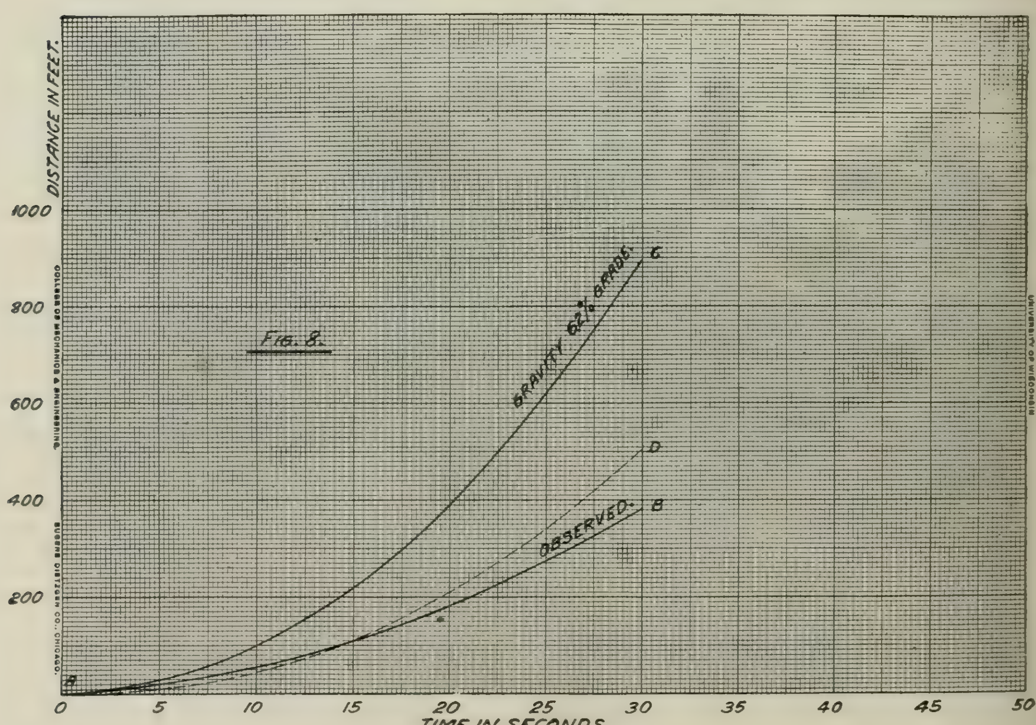



Fig. 8.

The Woods machine was arranged in the same way, though using a slide gear transmission. The Eldridge had a slide gear of a different type, and was free when drifting.

It seemed quite likely that this item of resistance was such that it should be considered, but while a careful examination developed indications of such resistance, it was so small that its effect at the

periphery of the wheel was too small to affect any of our calculations and could therefore be neglected.

As the "Eldridge" and "Woods" car runs were upon roads very nearly alike, it would probably be fair to average the results of those runs to get values for that character of road. Such average gives the following:

$$R = \frac{W}{16.08} \times \sqrt{.005118\,V + .05895} = W\,\frac{\sqrt{V + 11.5}}{224.8} \qquad (30)$$

| | | |
|---|---|---|
| If V = | 0, R (omitting W) = | .0152 |
| | 5, R | .0180 |
| | 10, R | .0206 |
| | 20, R | .0250 |
| | 30, R | .0286 |
| | 40, R | .0320 |
| | 50, R | .0349 |

These "average" lines are platted upon the diagrams, in connection with the figures from the observations. Fig 6.

It will be noticed that these resistances do not increase in as rapid a ratio to the velocity, as has been the popular idea, the increases being only as the square root of a very small function of the velocity.

Our curve is of the form of a parabola, and will apply to much higher speeds than we have been able to reach.

The diameter of the wheel with the pneumatic tire has much less effect upon the resistance than has that of the solid wheel. The solid wheel simply lifts the car over the obstruction met with, while the pneumatic tire is compressed when the obstruction is reached, and as it is passed expands, and resumes its original form, giving out practically the same amount of force, that was expended in compressing the tire.

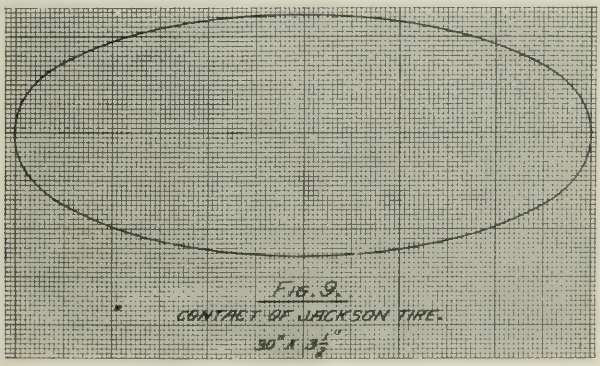



Fig. 9.

The tire in its normal state and at rest, is somewhat flattened at its point of contact with the ground, the form being elliptical and for the "Jackson" car, substantially like the sketch shown on diagram Fig. 9, six inches long. This tire is 30 by 3½ ins. The contact for the "Woods" car with its 36 by 4½ in. tire will be slightly

larger, while that for the "Eldridge," with its 30 by 3 in. tire, will be slightly less. The pressure upon the large tire will be between 60 and 65 or 70 lbs. per sq. in., while that for the lighter cars and smaller tire will be slightly less. Our experiments did not go far enough to get the effects of the diameter of wheels, or size of tires upon the resistance, but the indications seem to be, that where proper relations exist between size and diameter of tire and the weight it has to carry, and between reasonable limits, little difference may be expected.

To compare the results obtained from tests on good hard roads with those obtained from tests on the inferior roads, somewhat washed and with many small protruding stones we find, upon further reference to Fig. 6, that although the resistance curves for the good and for the bad roads are some distance apart on the diagram, yet they are practically parallel, so that the upper curves may be derived from the lowest by merely increasing the ordinate a certain constant amount.

Thus, taking as a basis the formula (25) $R = \sqrt{\frac{V + 13.4}{251}}$

which was obtained from the tests made on a good hard smooth road, it will be noted that (27), which is shown as the uppermost curve in Fig. 6, and which was obtained from tests on a badly washed macadam road in bad repair, represents 1.6% greater resistance at all velocities.

In other words the resistance on the bad road is greater than the resistance on the good road by 1.6% of the weight of the car, at all velocities. By adding this constant increment, which we may call "m" to our formula (25) for resistance on good, hard, smooth roads we get a general formula for resistance on all roads within the limits of our experiments, as follows:—

$$R = W \left( \sqrt{\frac{V + 13.4}{251}} + m \right) \qquad (31)$$

Where R = resistance in pounds,
W = weight of the car in pounds,
V = velocity in feet per second.
m = term depending on character of the road, varying from zero for good hard smooth roads to 0.02 for rough macadam roads in bad repair.

COMPARISON WITH MORINS RESISTANCE FORMULA.

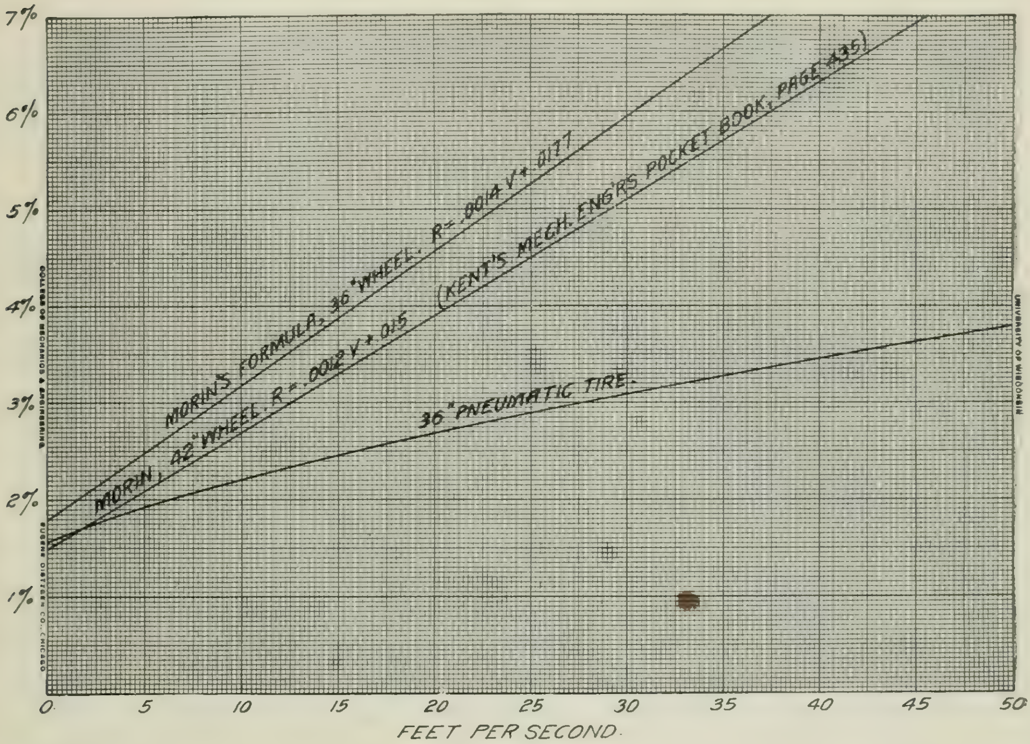



Fig. 11.

To illustrate the differences between our formulae for pneumatic tires and high speeds, and those obtained by General Morin, we add Fig. 11. The lower, curved line shows the resistances observed in the tests with the Woods Automobile, with its 36-inch tires; the straight lines show the resistances for wheels respectively 36 inches and 42 inches in diameter, calculated by General Morin's formulae, as quoted in Kent's Hand Book, page 435.

Note, that in each case there is a considerable initial resistance, required to start the vehicle from a state of rest. After that the resistance, by the General's formulae, increases directly with the velocity, whereas with pneumatic tires the resistance increases nearly as the square root of the velocity.

## DISCUSSION.

*President Arnold:* Mr. Hudson has certainly brought out in an interesting manner a novel way of measuring resistance in connection with vehicles, which gives us an opportunity to test our vehicles with comparatively small expense.

I was quite interested in two conclusions,—viz.: That the increase in resistance does not increase at the same rate as has been popularly supposed. Also that the diameter of the wheels has little to do with the resistance, when pneumatic tires are used. It would be interesting to carry these experiments further, in order to

see how much greatly varying diameters would effect the conclusion.

*Mr. J. C. Bley:* I have never owned an automobile, and as a matter of fact have not ridden in one very many times, but I have noted a few things that I wish to speak about. One is the difference between the present day conditions and those of General Morin's time, I think one thing was omitted, which is of importance in connection with the items of velocity and condition of the road, and that is, the use of ball bearings. I presume those automobiles were all fitted up with ball bearings. I think if we were to go back to the old conditions of large axles greased with heavy grease, it is quite likely Mr. Hudson's equation would have worked out quite differently. I think the ball bearing is probably equally important with the other items noted.

As President Arnold remarked, this method makes a very simple means of carrying on such experiments, as far as taking records is concerned. I can imagine, however, it was somewhat tedious working up those curves. Mr. Hudson might have emphasized a little more, the error that is likely to come, in measuring the diameter of the tire and so getting at the circumference. I think the method pursued is the only accurate one to depend upon.

I notice one little expression occurring two or three times; that is, the statement is made, that "W is omitted." I think that is an inaccuracy liable to trouble some of us who are not well versed in mathematical expression. We do not omit W, but make it equal to unity, and I think it would be better to put it in that form, say that we, to make the weight equal unity.

On page 670 the author refers to the sudden jolt or jar that is liable to occur when a railroad train comes to a stop. It seems to me this might be very largely due to the elasticity of the brake connections. When a railroad car comes to a stop the brake beam, support, truck frame, and various other connections are strung up to pretty high tension, and when the car finally comes to a stop they release themselves and produce an actual, though slight backward movement of the car. I think that occurs in many cases. The starting forward of the car would not imply that so much. That spring effect would hardly apply in the case of an automobile. It is simply allowed to come to rest by the general friction effect.

In the matter of finding the first point of a curve, I was wondering if the author had tried the method of fitting a circle to this curve on page 666. That is a method recommended by C. W. McCord of Stevens Institute, in finding certain points of tooth curves. I do not know how close a degree of accuracy McCord's method would give.

I think the paper is important in this way—that it shows what can be done with comparatively simple apparatus. Many of us are frightened from making experiments, thinking that it is

shown that some things can be done with comparatively simple means.

*Mr. W. L. Abbott:* I must confess that when I saw the title of this paper I thought it applied to some railroad matter, and did not study it and for that reason I am not well prepared to discuss the subject. If I had known it related to automobile work I should have looked into it.

I infer that the paper, instead of being "Notes on Road Resistances," is a description of a method to determine such resistances, and that the principle is that the retarding effect of the road resistance is a constant force, independent of velocity, and very similar to the effect of gravitation, and for that reason may be discussed similar to the formulas relating to falling bodies. The application of this to many purposes I can readily see, and one idea I presume would be to make a determination of a condition on the road by setting a vehicle in motion and determining the length of time or the distance which it would run before stopping when given an additional velocity.

Some of us are able to ride in borrowed automobiles who are not able to borrow this testing device. I think it would be a matter of interest if the principle might be still further simplified so these determinations might be made with a stop watch.

*Mr. J. H. Warder:* The author speaks in his paper of experiments having been made by General Morin about the year 1840, "to determine the resistance to traction encountered by carriages of various kinds on different road surfaces then in common use." I have here a book, which is in our library, containing that work of General Morin's which I have found at different times to be delightful reading. The title of the book is "Fundamental Ideas of Mechanics and Experimental Data," originally compiled by General Morin and afterward revised and translated by Joseph Bennett. It was published by D. Appleton & Co. in 1860. The portion relating particularly to draught of vehicles is very full and yet the mathematics are presented in such a simple way that anyone conversant with algebra can manage it without difficulty. There are many other portions of this book relating to the subject of mechanics which will also be of interest to the investigator.

The reason I mention this is that it may not be generally known that Morin's book has been put into English.

*Mr. G. T. Seely:* It seems to me that if the tests were to be made on various kinds of pavements we could get a comparison of the resistance on these different roads which would be of some value.

Pneumatic tires have a certain suction and if a hard tire or cushioned tire could be used to eliminate that suction, one might get values for comparative resistances on the different classes of pavements, such as ashphalt, brick, macadam, etc. It seems to me we would get practical benefit from an engineering standpoint, more than on simply one class of pavement.

*President Arnold:* I will say on that point that in 1892 Mr. Fred. Degenhardt and Mr. E. E. Keller conducted a series of tests here in Chicago with an automobile which they designed, and which they hoped to get adopted by the World's Fair authorities for use on the World's Fair Grounds in 1893. If I recollect correctly they found from tests of this electric vehicle that the resistance of a rubber tired vehicle was least on a brick pavement and greatest upon ahphalt pavement, the cedar block pavement being intermediate between the two.

The theory advanced by them at that time in a paper read before the Electric Club of this city (not now in existence, however), was that brick and cedar block pavement, being composed of a series of humps upon which the tires rolled, allowed the air to get underneath the rubber tires, while on asphalt pavement the tires flattened out to the exclusion of the air thus creating suction, and thereby increasing the resistance. I think if you will take an automobile and equip it with rubber tires, the resistance will be increased on the asphalt pavement.

I fully agree with Mr. Seely that some such tests on the city streets here would be very interesting.

I will ask Mr. Hudson if he will tell us where these experiments were made?

*Mr. Hudson:* The experiments with the Eldridge and Woods automobiles were made at Oak Park on Austin Avenue, Washington Boulevard and Jackson Boulevard; some were on asphalt pavement on west Washington Boulevard.

The experiments with the Jackson car were made on down-hill grade at Knoxville, Tenn. Around Chicago we could not find the hills, and at Knoxville we were unable to find any level roads.

## CLOSURE.

*Mr. Hudson:* General Morin's book was frequently referred to in preparing this paper.

In regard to tests on asphalt, macadam and brick pavements, we made some experiments along this line, and we were unable to detect any difference between the asphalt and macadam. With the brick pavement we thought there was a slight decrease in resistance but were not sure.

Referring to Mr. Bley's remarks about ball bearings, one curious thing that we noted was that the automobile showing the least resistance had plain bronze bearings; the other two had roller bearings.

We came to the same conclusion about the cause of the jar when stopping,—viz., that it was due to the spring in the frame of the truck.

In regard to the extent of the experiments, I will say that I think we tried every kind of a road on which anybody would care to ride at fifty miles an hour. We ran our experiments up to forty-

five miles an hour on roads on which, if they had been any rougher, it would not have been safe for a vehicle to run. So that the outside limits of the roads which can be tested at high speed are not very great.

Mr. Bley's suggestion that we "make W. unity" instead of "omitting W.," is a very good one, and the change makes the final steps of the demonstration much clearer.

The drawing of the various curves, in actual experiments, is not so laborious as at first sight may appear. Any rough outline will answer as a graphical aid to the eye, though a carefully drawn curve will serve better in detecting any mistake or irregularity in recording the time and distance. The demonstration is quite lengthy, but the calculations required to reduce the observations and arrive at the formula for any new experiment are all included in equations (18) to (24). After counting the seconds and revolutions we merely solve for two unknown quantities, a and b, and substitute their values in the formula (17).

We found that the retarding force is not the same at all velocities as suggested by Mr. Abbott, in that respect differing from the accelerating force of gravity, which is constant at 32.16. Therefore the experiment cannot be reduced to a single observation with a stopwatch as suggested. Two stopwatches, and two measurements of distances would be sufficient, however, to give accurate results at the two velocities observed.

## ELECTRIC POWER SYSTEMS IN SOME EUROPEAN CITIES.

Abstract of address before the Electrical Section.

October 19, 1906.

P. Junkersfeld, M. W. S. E.

*Electric Transportation.*

In London, or rather in London county, with its 6,500,000 people, the transportation problem is by no means completely solved. In the denser section of the city proper, the narrow and crooked streets are crowded with vehicles of all kinds; the regulation two-story London Omnibus covered with advertising signs, the great variety of carriages or "four-wheelers," the hansoms or "two-wheelers" with their remarkably skillful drivers and the more recent automobile bus all leave but little room for tramways or surface street cars. A well known straight-away electric underground railway, about fifty feet below the street level, about eight miles in length, long known as the "Tupenny Tube," has been in service some six years. This road has its own power house known as the Shepherd's Bush Station having a capacity of about 800 kw. and delivering three phase, twenty-five cycle current at 5000 volts.

Most of the underground systems, and which are far more extensive, are nearer to the surface. In a genaral way they radiate from an inner loop of irregular outline. A large number of these systems are now being operated through ownership lease or working agreement by the Metropolitan and Metropolitan District railways and known as the "Yerkes" system. This system has been in the process of development and under construction for several years. The electric power supply has been provided on an extensive scale and is practically completed but there has been much delay in completing the electrification of the various railway lines. The power house known as the Chelsea Station delivers three phase, thirty-three cycle current at 12,000 volts to a system of rotary converter sub-stations. The rated capacity of the power house is 44,000 kw. but the maximum load previous to the date of the writer's visit was only about 15,000 kw. The electric power for operating the tramways of London County will be furnished principally from the new Greenwich Station, which has only been in service a few months.

Paris also has a very extensive and apparently well patronized electric underground system. This is being extended at a rapid rate both on the right and on the left bank of the Seine. It is known as the Metropolitan Railway and supplies a large part of the necessary electric power from its own De Bercy power house. The latter has a rated capacity of 28,000 kw. and delivers three

phase twenty-five cycle current at 5,000 volts to a system of substations. The additional power needed is purchased from a bulk electricity supply company which has built the new St. Denis power station about twelve miles in a north-westerly direction from the center of Paris. Last June the rated capacity in service in this new power house was 20,000 kw. but 30,000 kw. additional capacity was under construction. The surface transportation in Paris consists of various systems; overhead trolley, underground trolley, contact systems, gasoline motor cars drawing trailers, horse cars, two-story omnibuses and some automobile buses; in short, the underground transportation is good and the surface transportation generally bad. Cabs and carriages, with and without taximeters, are used to a very considerable extent.

In Berlin with its 2,500,000 population the surface transportation is probably better but the underground transportation is not nearly so extensive as that of London or of Paris. In Berlin there is also an elevated railway which gives good service but is quite limited in extent. Practically all of the electric power for transportation in Berlin is furnished by the Berlin Electricity Works. Taximeter cabs and taximeter automobiles, which are very numerous in Berlin, are a great convenence and apparently quite profitable for their owners. The Stadt-Bahn and Ring-Bahn, an extensive system of steam railroads, carry very large numbers of local and suburban passengers. Plans are reported well under way for the electrification of these extensive systems.

The electric transportation in most of the moderate size cities visited such as Newcastle, Glasgow, Edinburgh, Belfast and Dublin differs rather strikingly from that in American cities of similar size, in the general use of double deck cars. These double deckers are also used in London and Paris but were not seen in Berlin, Frankfort or Cologne. In nearly all of these cities, of large and moderate size, the conjested business districts are much less pronounced than in American cities of corresponding size; this results in a much shorter average haul per passenger and usually in less frequent car service during morning and evening hours.

*Electric Lighting.*

In Great Britain 240-480 volt distribution system using 240 volt lamps are employed to a very large extent while in America such systems have thus far failed to become permanently successful. One of the several reasons is the general use of a poorer quality of incandescent lamps. The lighting companies ordinarily do not furnish lamp renewals, there is no general lamp testing bureau and the individual customer buys his own lamps as best he can, which is often in a hardware store. Such lamps usually take 3.5 to 4 watts per candle and very often even more. Under this condition there seems to be very little incentive for the lighting companies and municipalities to maintain a high grade of electrical service.

In London, the electric lighting industry is carried on by a large number of small companies and municipalities, each operating in its assigned territory. This has resulted in wide differences in engineering development and in lack of standardization. Two-wire and three-wire direct current and alternating current systems are used. The lamp voltages vary from 100 to 250 volts and the frequencies, for lighting service, through an equally wide range. With such a multiplicty of comparatvely small lighting systems, each with its own power house, and many of which are no longer modern, the best economy in the generation and supply of electricity of course, is impossible. At each of the last two sessions of Parliament, bills were presented, asking for rights to generate and sell electricity in bulk from two or three large new modern power houses but failed to pass. Additional bills will undoubtedly be presented in the future. In the meantime, however, electric lighting and general power developmnt is practically at a standstill in London.

In Paris the wholesale supply of electricity has been arranged and is well under way. The company operating the new St. Denis Station has started a wholesale supply and a second large wholesale supply power house in south Paris is under construction. However the franchises of many of the retail distributing companies, who in Paris also operate each in an assigned territory, are about to expire and thus far have not been renewed. These local disputes in some parts of Paris have greatly retarded electric lighting development and have given gas lighting an advantage which has been promptly and effectually followed.

In Berlin practically all of the electric power needed for electric lighting and general power is supplied by the Berlin Electricity Works from its very extensive central station system. In the central portion of the city 110-volt lamps are used, the distribution being 110-220 volts. In the outlying portion 220-volt lamps and 220-440-volt distribution is used. All of the above is direct current. In the suburbs of Berlin alternating current is distributed to individual customers. The electric light industry is progressing very rapidly indeed. While the company does not furnish lamp renewals there is ample opportunity for testing of lamps and the average customer seems remarkably well informed on electric lighting and illumination. The ordinary incandescent lamps were all 3.1 watts per candle power. We also found a large number of the more modern incandescent lamps in use, all of which were operated on direct current. Among these might be mentioned the Nernst, osmium and tantalum lamps. The wolfram or tungsten lamp was given its first public exhibition last June and created a considerable stir in engineering crcles. This new tungsten lamp is probably the most important advance that has been made in the electric lighting industry in the past twenty-five years. The gas lighting in Berlin seems to have also reached a very high standard.

In fact the art of electric and of gas illumination seems to have been given perhaps more attention in Berlin and in Vienna than in any other two large cities in the world.

*Power House Equipment.*

One of the distinctive features of European power houses is the almost universal use of economizers and as a result of this the use of electric instead of steam driven auxiliaries. One of the principal reasons is the higher cost of coal, which in Berlin, durng the past year has averaged about $5 per ton for a grade of coal having 12,000 b. t. u. and ten per cent ash. The power houses in Great Britain more nearly resemble American practice than do those of Germany and France.

Water tube boilers and automatic stokers are now being used quite generally, especially in the larger power houses. In Great Britain overhead coal bunkers are frequently provided but in Germany and France where steel construction is more expensive and where power houses seem to be located on less expensive real estate the coal is stored in separate coal storage houses or stored in the open. A very large portion of the coal used in power houses is transported by water instead of by rail.

The number of power houses using turbines exclusively are still comparatively few. Out of fifteen power houses visited eight employed reciprocating engines, four had both engines and turbines and only three had turbines exclusively, the last mentioned being the Chelsea Station in London, the Carville Station in Newcastle and the St. Denis Station in Paris. Among the latest and most promising turbine installations at the time of the writer's visit might be mentioned the 3000 kw. Curtis type installed by the Allgemeine Electricitats Gessellschaft in the Oberspree Station of Berlin, the 5000 kw. Parsons type installed by Brown, Boveri & Company in the St. Denis Station of Paris and the 3000 kw. Parsons type installed by Willams & Robinson in the Port Dundas Station in Glasgow.

Leading engineers did not seem to be particularly enthusiastic over gas engines. They are apparently very little used in the larger cities.

There is, however, considerable discussion about chemical processes in connection with electric power systems and about various schemes for utilizing waste heat. In one instance the writer saw a 1500 kw. steam turbine plant where boilers were supplied entirely by waste gases from coke ovens. This plant was operated in multiple with a large transmission system, the amount of load on plant being regulated automatically by the supply of waste gases to the boilers.

The electrical equipment, particularly in the modern power houses in Great Britain is very similar to that in this country. In Germany there seems to be some timidity about high voltage generators, very few of which exceed 6000 volts. A few of the latest turbo-alter-

nators have been built for 10,000 volts and have also been equipped with smooth rotors instead of with revolving fields having definite poles. During the past few years the switch equipment in many large European power houses has been entirely reconstructed and oil switches installed instead of the former air brake knife switches. On the continent most of the oil switches have the three-conductors in a single oil vessel instead of in separate oil vessels and compartment. Nearly all oil switches are remote controlled and equipped with overload and reverse current relays. The generator voltages in the stations visited ranged from 5000 to 12,000 volts. The frequency in the power stations which supplied railway service exclusively or in large part, was usually twenty-five cycles. In other power houses the frequency was usually either forty or fifty cycles.

### *Transmission Systems.*

The transmission systems observed were all underground and most of them were operated independently at the sub-station, i. e., two lines entering a sub-station were not tied together on the same bus bar. This general scheme has become known as the so called "radial system" and is recognized as representing a slight sacrifice in economy in order to secure in the present state of the art the best reliability of service in a transmission system supplying large sub-stations. The "inter-connected system," in which incoming lines at sub-stations and also adjacent sub-stations, are constantly tied together, was also used to a considerable extent. This system affords better economy in transmission but is also more largely at the mercy of automatic protective devices. The so called "ring system" in which a single cable from the power station supplies a number of sub-stations in series and finally returns to the station after having formed a loop or ring, is employed at Newcastle. The cable between two adjacent sub-stations is equipped with overload relays at each end, which relays are connected in opposition or "balanced" by means of a two-conductor pressure wire paralleling the main high tension cable. In case of a breakdown in the cable the "balanced" condition no longer obtains and the relays instantly disconnect the particular piece of cable at each end. The continuity of service to sub-stations is, however, not interrupted even though such services may be somewhat impaired. This ring system was developed and apparently is well adapted to the conditions at Newcastle, i. e., a large number of comparatively small substations (1000 kw. capacity and less). This transmission system as laid out covers a manufacturing and mining dstrict about thirty miles long and eighteen miles wide and is an extremely interesting development.

The principal power transmission systems of Paris, Berlin, Frankfort, Glasgow and one of those in London were operated sectionalized. In Berlin, where sectionalizing is carried perhaps to the extreme, the three large stations were operated entirely independent, each supplying its own group of sub-stations. Each

sub-station in turn supplies its own independent net work. The two largest generating stations are each operated in two or three sections. The opinion of most of the leading engineers was in favor of a reasonable amount of sectionalizing in very large high tension alternating current transmission systems.

### *Sub-Station Equipment.*

In sub-station equipment, except possibly such as is used for railway service, there is very great lack of standardization. Two of the large exclusively railway power systems in London as well as the metropolitan underground system in Paris and the tramways system in Glasgow used rotary converters very similar to those used in American practice. Many of the other systems employed a varied assortment of induction and synchronous motor generator sets and some of them used a type of converting unit known as asynchronous motor generators. In Berlin, however, where all of these various types were found in service, the very latest installations consisted of a special type of rotary converter. These rotary converters differ from those commonly used in this country for lighting service by the absence of the independent regulating apparatus known as the induction regulator. The range in voltage which with the rotaries in Berlin was much more than ordinary, was secured by means of an additional set of fields thus increasing the length of the unit and in effect placing the regulator on the shaft instead of having same in the form of a separate piece of apparatus.

The amount of switching apparatus and the number of automatic protective devices and instruments was in most cases very considerable. In some instances, particularly in Berlin and Glasgow, the provisions for locating trouble on the low voltage distribution system were complicated and extensive.

The character of sub-station buildings in most cases was very good and thoroughly in keeping with the requirements. Many of them allowed much more liberal room for apparatus than would be considered advisable with the very high real estate values that often obtain under American conditions. In the Berlin system as well as in the Metropolitan Railway of Paris each sub-station was equipped with one or more large storage batteries.

### *Underground Construction.*

The so called solid system of underground construction is very largely used in Great Britain. This consists of cable laid in troughs or a similar arrangement by means of which the cable is completely enclosed with some sort of asphaltum or similar compound. The cable cannot be removed except by digging a trench its entire length. The more recent large installations, however, employ the conduit or "draw in" system, in which underground cables can be installed or removed at will after the conduit and manholes are once provided. This system is becoming quite popular in the larger cities. The choice as between the conduit and "solid" systems in

these cities is now usually dependent upon the number of cables which it is expected ultimately to install. If the engineers believe that more than two or three cables are at all likely to be needed the conduit system is preferred. Many English engineers maintain that the "solid" system is the more lasting and less susceptible to electrolysis troubles but this is still a more or less open question. On the continent a so called "buried" system is employed almost exclusively. It consists of laying lead covered cable protected by armor and jute directly in the ground.

One of the reasons why the "solid" and "buried" systems are usually used in Europe especially for the house-to-house distribution is the absence of excavated space under sidewalks and the strip of ground which is usually found between sidewalks and building lines. This latter strip is usually paved with a very cheap rough mosaic pavement under which the distributing mains can be buried. The service taps to such mains can then readily be made at a minimum cost and with the minimum of inconvenience to the public.

The necessity for a very high standard of electrical service, as previously stated, is not so urgent in Europe as in this country. On the other hand the cost of repairs to the "solid" and "buried" underground distribution systems is usually much greater than where the conduit system is employed. As a result the distributing mains and low tension feeders are fused comparatively light and many elaborate methods for keeping track of the insulation resistance are followed. This is expensive and necessarily results in frequent interruption of service often of several hours duration.

## *Conclusion.*

The electric power systems in the larger cities of Europe are on the whole thus far not as extensive as the larger systems in this country. In all undertakings where the conditions of the electric power problem are similar the solution is usually also similar. Electric transportation on the whole is not so general as in this country, interurban electric railways being comparatively rare. The amount of electric lighting per capita is also not so great particularly in the smaller cities. The development in incandescent lamps while not so good in Great Britain has reached a higher plane in Germany and Austria than in this country.

In electrical manufacturing and export trade a very large business is being developed. One of the very large electric manufacturing companies in Berlin employs 30,000 men and makes very heavy shipments, particularly to South America and South Africa. Another manufacturer who had many years experience in America has, in Berlin, within a very few years built up a business, largely export, which employs 5,000 hands. American manufacturers with their wonderful capacity for standardization and production in large quantities should have little to fear in the world's competition, but are by no means in a position to rest on their oars.

# THE SUPPRESSION OF INDUSTRIAL SMOKE WITH PARTICULAR REFERENCE TO STEAM BOILERS.

A. Bement, m. w. s. e.

*Presented Oct. 17, 1906.*

The problem of burning bituminous coal without producing smoke can be divided into two distinct features, one referring to legislation and its enforcement, the other to the technical or engineering phase of the matter, and it is more particularly the latter feature that is considered in this paper. It is the author's wish to emphasize certain fundamental principles upon which the complicated and difficult problem of smoke production and suppression rests, rather than attempt the detailed treatment of any individual condition or set of conditions.

It is a recognized fact that bituminous coal can be burned without smoke; also that the consumption of the volatile gases results in increased economy, and while great improvement has been made, there is very much still to be accomplished, and the great and foremost requirement is a technical one, demanding not only a recognition of the principles involved in smokeless combustion, but better engineering practice as affecting design of plants and furnace apparatus. In the author's opinion, the people who are to blame for present conditions, may be divided into three classes in the order of their responsibility:

*First*—Manufacturers of furnace apparatus.

*Second*—Consulting engineers and architects.

*Third*—Purchasers who operate the apparatus.

In considering the matter from the standpoint of manufacture, the important fact should be emphasized, that with one possible exception there are, strictly speaking, no smokeless apparatus made. This single exception will be mentioned later, but it is first desirable to outline the requirements governing smokeless combustion. They are—

*First*—Uniform evolution of the volatile gas, which requires with a stoker a positively uniform feed of the coal.

*Second*—The location of a chamber of sufficient length or capacity between the fire grate and exit to the boiler, to ensure that the volatile gases shall become thoroughly mixed with the air which enters with them.

Such chamber, which the author has called a furnace, to distinguish it from the grate, must, of course, be made of refractory material to enable it to withstand the heat, and its walls necessarily become red hot; this has caused many people to believe that the high temperature in itself was the cause of the volatile gases being burned, failing to take into consideration the fact that the most important requirement is a thorough mixing of the gases with the

air in the chamber. Failure to realize this fact has resulted in disappointment with many brick arches, "Dutch ovens," etc. The chain grate, owing to its feed of coal being on a horizontal line, ensures a positively uniform rate in the feed, and consequently there is a steady evolution of the volatile gas, which will be burned if there is such furnace located between it and the boiler, and this apparatus may properly be called smoke-proof, because it is impossible for the operator to either cause, or allow the coal to be fed in other than a steady and uniform manner.

Even when a very large furnace chamber is used with any form of stoker (other than a chain grate) or a hand fired grate, a smokeless condition is dependent upon careful manipulation. For example, with a hand fire, if too much coal is added at one time, the evolution of gas will be greater than the mixing capacity of the chamber; or, with sloping grate stokers, when a large quantity of coal is poked or slides down the grate, the result is the same as when a large charge of coal is added to a hand fire. Thus the fuel feeding apparatus or method of manipulation, must not overtax the mixing capacity of the furnace chamber, if a smokeless result is to be secured.

The accompanying illustration shows the latest and best type of smoke proof steam generator, its furnace chamber being formed by tiles covering the lower row of the tubes of the boiler. It is not a patented apparatus and may be adopted by anyone who wishes to do so. In fact, many boiler plants now installed, may at small expense be altered so as to conform to all of its essential requirements. While this particular improved apparatus has already been built when demanded by purchasers, no manufacturer is willing to erect it unless required to do so. The nearest approach to a smoke proof apparatus in the form of a complete steam generator, offered by any maker, consists of a brick arch as an essential adjunct for the direction of the gases against the tubes of the boiler, and when this manufacturer installs a chain grate under this arch, it becomes the above mentioned exception to the rule. This does not mean, however, that a purchaser may not buy a boiler from one maker, a stoker from another, and with a little engineering produce an apparatus which is strictly smokeless, but that an entire apparatus of satisfactory character as a unit, cannot be purchased from any other manufacturer.

For a clearer understanding, it is essential that furnace apparatus be considered in two classes, one which is smoke proof, the other depending upon careful manipulation for good results. This latter class may also be separated into two divisions, those which by reasonably careful working will be smokeless, and others, which it is very difficult to operate without smoke. Thus there are three grades of apparatus, the perfect, the moderately good and the bad.

The effort of health departments and smoke inspection bureaus should be to enforce the adoption of the perfect apparatus, proper

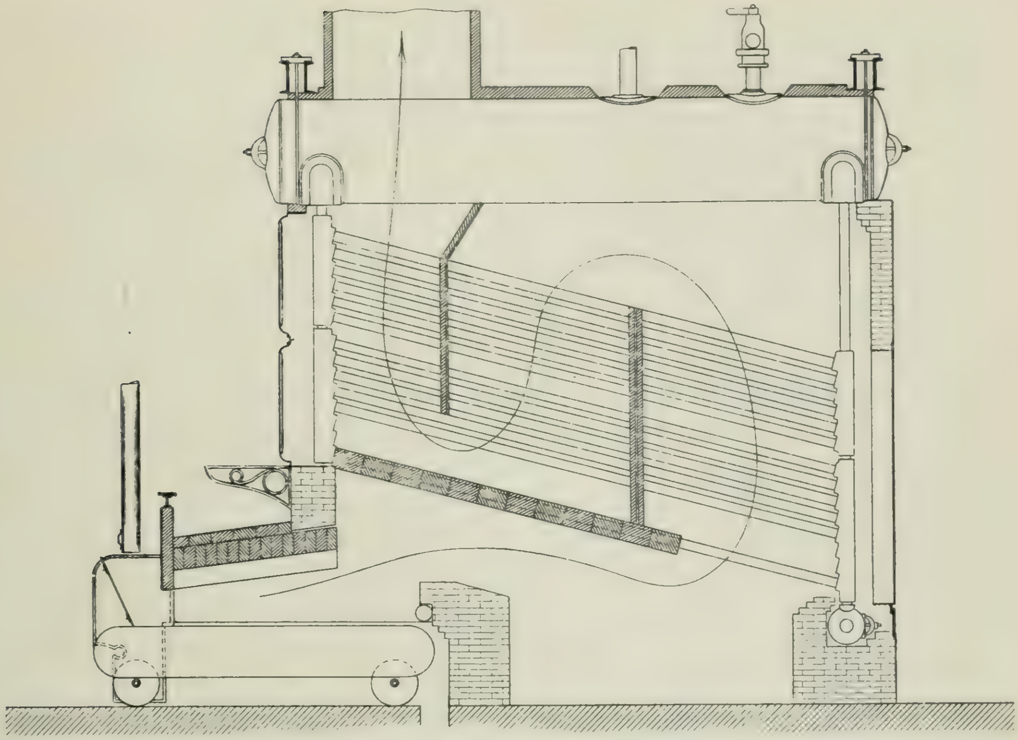


FIG. I. SMOKE PROOF STEAM GENERATOR.

manipulation of the moderately good and the abandonment of the bad. Unfortunately, however, the most serious offenders,—the manufacturers, consulting engineers and the architects, are not affected by the smoke laws, therefore can only be reached indirectly through the purchaser who bears all of the burden. Thus the only alternative is to enforce the laws in such manner as to be most effective.

The position of the smoke inspector from the engineering standpoint is a difficult one. As a general rule he is an administrative official, appointed or elected for the purpose of enforcing laws, and his time and efforts are taken up in such work, and the character of the requirements largely determine the training of the man selected. It necessarily follows that often he is not an engineer, at all events to that extent necessary for the solution of the difficult engineering problems encountered; the conditions under which he must necessarily work, prevent to a very great extent his becoming technically proficient, because the tendency would then be for certain apparatus to be recommended in preference to others; this immediately results in trouble, caused by the influence of manufacturers who would not be favored. As it is, if a prospective purchaser applies to a smoke inspector for information as to the most desirable apparatus to be procured, he may be referred to a number of plants which are examples of good practice, in which he may find a variety of apparatus, and selecting one of these often finds after it is in service, that under *his* conditions it is

not satisfactory; upon further investigation, he discovers that others labor under as much difficulty as he, and thus often feels that he is an innocent victim of circumstances.

There are many plants where conditions render it difficult to correct the apparatus except at great expense. Such cases present a real problem to the smoke inspector. On the other hand there are many owners who do not try to improve conditions, in fact, make no effort to discover whether or not they can correct their practice or the apparatus, and make promises they do not intend to fulfill. One of the most common excuses is, that their boilers are "overloaded" and for this reason they can do nothing, and unless the inspector is an engineer and familiar with this phase of the matter, he often encounters a seemingly insurmountable difficulty, when in reality these same owners, for reasons of economy, would not work their boilers at a lesser capacity. As a matter of fact, the practice which ensures a smokeless condition, also results, as a general thing, in the production of a large capacity. The remedy with such owners is a drastic enforcement of the law.

In view of the fact that the greatest trouble is one that may be overcome by better engineering practice, and that there is no accepted or recognized independent source of information for the guidance of well intending purchasers, it is recommended that the Engineering Experiment Station of the University of Illinois and the State Geological Survey, present information to the people of this state, which, coming from such sources, may be accepted with confidence and used to advantage.

## Discussion.

*Mr. W. L. Abbott*—(Chairman)—For something over 20 years I have been in the business of making smoke, and during that time I have been called into court more times than I can now remember. All of this prosecution (or persecution as at times I thought it was) inflicted upon me and upon others engaged in smokemaking, did not appear to have much effect in reducing the amount of smoke which fills the air of our city. Within a few years, however, this subject of suppressing industrial smoke is being considered in a more scientific way. The City Health Department and others are taking up the subject in a rational way to assist the owner in so perfecting his furnace that smoking will not be necessary. Among the organizations which are engaged in this work in the city at the present time I will mention the City Club of Chicago, which has a representative here tonight, Mr. Robert H. Kuss, and I will ask him to open the discussion.

*Mr. Robert H. Kuss*—On behalf of the Committee on Smoke Abatement of the City Club of Chicago, the speaker wishes to thank the writer of the paper on what appears to us to be a very timely subject. The Committee recognizes that in smoke abate-

ment it is confronted with a larger problem than the enforcement of the law and appreciates that unless engineering thought comes to the rescue, the law itself may become inoperative because of impracticability.

If the speaker were inclined to question the analysis of the problem as stated by Mr. Bement, he would be tempted to add one more factor as a responsible force for the present condition of unclean atmosphere and would consider that factor third in importance. For it appears that the people who control the coal output close at hand and who are entitled to the local market by reason of the proximity of the coal producing fields, have been derelict in their duty to see to it that their product receives just treatment in the boiler room instead of having that product burned in furnaces and by methods that answer well enough for coal from other fields. Were it not for the fact that the belief is entertained by bodies such as I represent (The City Club of Chicago) that bituminous coal mined in our state and in states close at hand can be burned without smoke and with economy, which, everything considered, makes it the logical coal to use, there would probably be little enthusiastic support for the smoke abatement cause, costly though such indifference would be to the general public. To repeat the substance of a previous remark, it is the duty of those who have in common the consumption of a local product to lend every aid in making clear that, without special favor being asked, it is possible to consume that product without detriment to the community and with a saving to the consumer. Nor can our local coal producing interests maintain that the matter of the smokeless, economical consumption of their coal is not sufficiently well understood, for we have before us a refutation in the paper coming from the pen of one from our own midst. Granting that the requisite knowledge is not disseminated declares judgment against the local coal producer and simply accentuates the charge as made above without revealing a mitigating circumstance.

Approach the average man who sells boilers and he will devote most of his time telling you about the superior advantages of his contrivance without dealing with the first essential of his proposed installation, the combustion facilities, though he protests against a change from his standard gas baffling for fear of sacrificing one of his talking points. You can hear a great deal about this and that scheme of gases sweeping along or across tubes as having some mysterious effect on water circulation, but you cannot find much information as to the probably effect of his device as regards the completeness of combustion and the cost at which this is brought about. Hence, a great deal of missionary work must be done among the manufacturers of furnace apparatus, and quickly, too, lest new plants or rehabilitated old ones continue the same mistakes that have been made in the past.

The speaker cannot refrain from alluding to the feature evidently intended under the second item of the paper, "engineers and architects," where the fallacy is pointed out of engaging a specialist of one kind to recommend or decide upon an important matter not strictly his main problem. It is something like calling in a dentist to prescribe for a fever; he may be better informed than the patient, but as long as a physician can be called in, that is the obvious thing to do.

The paper advances matter that has its greatest usefulness in assisting the decision of what to do in the future and as such comes close to showing us something that will meet the smoke-proof requirement in plants sufficiently large to make the installation of mechanical stokers practicable. Where stoking is done by hand with its consequent intermittent evolution of volatile gases, it is not so certain that the combustion chamber is of itself sufficient to be classed as smoke-proof. Upon that matter something will be said later. When it comes to plants already installed, it is not so easy to find a remedy and as we are living under conditions of what has been built, the subject must necessarily be broadened to encompass that field also.

Smoke prevention devices as attachments to furnaces very often requires more intelligence, care and attention than would be demanded for the same effect without them with more attention to the details of firing direct, as by alternate, and more frequent firings on a hand fired grate. Moreover, the usual principle of these devices is the admission of an over-excess of air above the fire attended by more complete combustion, perhaps, but at the expense of a lower temperature. The mere mention of intelligence in firing, reminds us of a large percentage of plants that are improperly conducted. In such cases the smoke inspection service finds its best usefulness, in opening the eyes of those higher up to the economy of conducting smokeless power plants.

Attempts at making furnaces smoke-proof are often attended with expensive experiments which finally exhaust the enthusiasm in the work. Therein lies one important advantage of the tile roof furnace as proposed in the paper in that attention to details in the first place makes the apparatus relatively cheap in maintenance. Again, the installation of deflection walls is often left to incompetent persons who in their enthusiasm in following up one idea seriously injure some other department, mainly available draft over the fire.

In the discussion which follows it is not the purpose of the speaker to lay claim to originality or even to appear to do so, but rather to emphasize certain features of combustion that have often been touched on but lost sight of because of the greater importance attached to the other phases of the subject.

Viewed without reference to the effect upon the community that suffers from the emission of dense smoke, it may be stated

with some degree of certainty that the economy of a plant cannot be accurately gauged by the visible behavior of the chimney, first. because dense smoke is only an index of the bad combustion condition in that the loss due to the incomplete combustion of invisible gases may be more serious than the loss due to free carbon unburned; secondly, because an absolutely smokeless chimney may indicate that one of the conditions that admits of complete combustion has been more than fulfilled, resulting in an expensive heating of a needlessly large excess of air to be rejected later on without delivering to the heat absorber its just share of the heat it contains. Again, it is possible for one portion of the fire surface to admit a large excess of air at the same time that another portion evolves partially burned gases and free carbon, all not becoming intimately mixed. The stack gases in such a case result in an apparently incongruous analysis in that a high percentage of free oxygen is present together with unburned gases. A case in point is a chain grate furnace of short ignition arch that allows the gases from the front part of the grate to curl up into the water tubes while the free oxygen coming through the thinner back fire short-cuts into the tube region farther back.

The foregoing comments bear out the assertion that not enough attention has been paid to one of the prime requisites of economical complete combustion. The part that requires more treatment is that of the mixture of all the constituents that may combine to evolve heat, or as Mr. Bement states it on page 2 of his paper. "the most important requirements is a thorough mixing of gases with the air in the chamber." Upon that one point I choose to dwell.

First, a mixture of gases is made possible by a tile roof furnace in that the gases distilled from the front part of the grate are compelled to pass directly over those that rise from the back part. which fact in the case of a chain grate means the mingling of volatile gases from the front with the excess air of the back. Again, the downward slant of the tile roof is an aid also and ample space provides room for combustion to become complete if the distillation of volatile gases is continuous.

Secondly, mixing can be accelerated by the use of air or steam jets in a furnace with an ignition arch and a tile roof. The speaker does not advocate the promiscuous use of steam jets, but favors the employment of two fan shaped jets directed so that the steam stream if continuing in a straight line will impinge upon the ignition arch, say, six inches in front of the rear edge of the arch, the stream directed forward from a point a little below the top of the bridge wall. With a chain grate the latter is very important, lest the jet accentuates a fault by drawing through the thin back fire too much air. Steam is to be preferred to air both because of availability and because of the greater heat absorbtion ability of steam which tends to reduce the temperature of the jet

pipes. It may be contended that the device would tend to reduce the draft about the fire at the front part of the grate and have exactly the effect not desired. My answer is that we are not concerned so much with where the air comes from as with how it is employed. In deciding just how the jets shall be directed, let us not forget that the ignition arch to be of most service fulfills the important function of accelerating gas distillation by transmission of heat from the back fire to the front by radiation.

Thirdly, the use of the impediments in the combustion chamber behind the bridge wall has long been recognized as a means of mixing gases, as note the wing walls employed by Prof. Kent. The purpose of the walls just mentioned is to force the gases which pass over the bridge wall in a layer of rectangular section, with larger dimension horizontal, to assume a layer of rectangular section, larger dimension vertical. The speaker believes the arrangement can be improved. Note that the wing wall scheme employs one opening in the center of the combustion chamber This opening must necessarily be large enough to permit the passage of gases in a widely expanded state due to high temperature. The employment of an impediment made up of several pillars standing on the floor of the combustion chamber forces the gases to follow paths something like that shown by the arrows in the accompanying Figs. 2 and 3. A comparison of the pillar

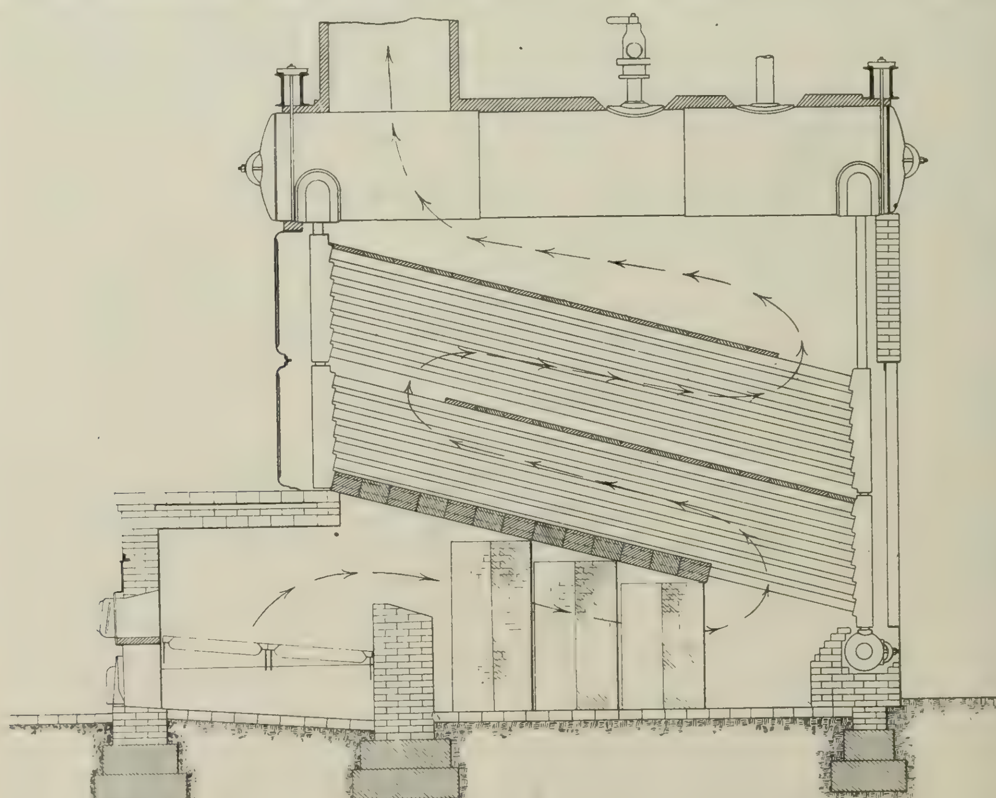


FIG. 2. BOILER PROVIDED WITH TILE FURNACE ROOF AND PIERS FOR MIXING THE GASES, EQUIPPED WITH HAND FIRED GRATE.

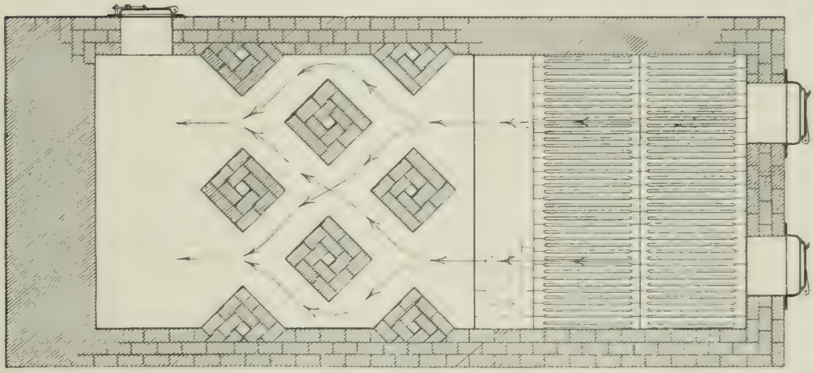


FIG. 3. PLAN OF APPARATUS SHOWN IN FIG. 2 ILLUSTRATING MIXING PIERS.

scheme with the wing walls indicates at least two points of advantage in favor of the former, viz:

(a) Less harmful effect on draft in that large aggregate area of gas passage may be gained with the same or better gas mixture.

(b) More regenerative surface, important where the evolution of volatile gases is intermittent as with a hand fired furnace.

By attention to the details of construction which follow the advantage of the wing walls of greater stability is met to a large extent.

(1) To be made of ordinary size fire-brick laid in pillars not less than 13 ins. by 13 ins. in section—(This means four bricks to a course with a square space in the middle to be filled in if found advisable).

(2) To be laid in very thin fire clay.

(3) The pillar bases to be spread out for stability.

(4) To be built up close to the tile roof (or shell in the case of a return tubular boiler.)

(5) Rows of pillars located with reference to adequate gas passages, but as far forward as such will permit.

Special large brick are not a success especially if used to span, as in the building of a check-work combustion wall. Experience teaches that the best work built of the arched or spanned plan fails in the high temperature of a combustion chamber. Moreover, whatever device is employed it should be simple enough in construction to be erected by an ordinary mechanic.

We now come to the part of the subject which does not admit of generalization, i. e., where shall a mixing device be installed? It all depends upon the available draft. Any mixing device is an impediment and consequently for a given stack draft the better the mixing device the less the effective draft over the fire. On the other hand, the better the mixing device, the less air needed to bring about complete combustion, or, stated in another way, the higher the resulting temperature from combustion with its consequent greater usefulness for the heat absorber employed. So while there may be a gain by the judicious use of a mixing device it can readily be seen that it does not follow that such are to be

recommended unless draft facilities are present. The speaker, without trying to establish a precedent which may be wrong, is accustomed to overlook mixing walls where the draft pressure is less than 0.6 of an inch of water taken at a point immediately after the gases leave the heat absorbing surface. This figure undergoes modification depending upon the condition of the setting. Incidentally it may be stated that it appears more to the purpose to deal with available draft over the fire rather than chimney draft, but because of greater attention paid in the past to stack draft, the speaker's views are not as secure as to the best figures to assume for draft over fire. Moreover, the matter is complicated by the fact that draft over fire is a greater variable than chimney draft, depending on fire conditions such as thick and thin fires, clean and dirty ones and the like, while the latter is less dependent upon these.

While we are dealing with stack draft let us not forget some of the expensive mistakes inflicted upon the owners and operators of buildings who for the sake of meeting someone's idea of where the stack must go, are forced to pay dearly for a tortuous path for the products of combustion that reduces the usefulness of the stack.

An analysis of the views of the people who are powerless to control the smoke nuisance except through their representatives in the smoke inspection service, shows that the demands thus far made have been tempered with reason. The speaker has occasion to know that, in Chicago at least, the feeling for clean atmosphere is very prevalent and deep seated and that conditions must gradually improve month after month or result in more insistent demands for the enforcement of the law. Those who have really studied the subject have as a foundation to work on, a reasonable law if enforced without favor. They feel that the detection of persistent violators is not extremely difficult, but realize the danger of granting immunity to those who ask for it on excuses entirely inadequate for the situation. Moreover, there is a feeling that the progressive fine method gives a lever which should be employed in every case and that the following of advice given by the smoke inspection service is not a legitimate excuse for immunity thereafter. Having the evidence at hand to prove conclusively that the smokeless consumption of any coal is both possible and economical, gives encouragement to the clean chimney agitation and leaves not a single economic reason against the enforcement of the laws to cambat.

*Mr. Abbott*—We have with us this evening an engineer from a plant which burns the cheapest kind of western screenings without smoke. If he could tell us how we could do it everywhere else, he would confer a great favor. I refer to Mr. Frank Elliott, Chief Engineer of the Northwestern Elevated R. R. power house.

*Mr. Frank Elliott*—Referring to the matter of automatic stok-

ers and their economical operation without producing smoke. I will say that in my opinion, only reasonable care is necessary with the Murphy furnaces, such are we have at our Fullerton Ave. Power House.

The common difficulty in the operation of this stoker, is in allowing grates to get bare, magazines to get empty, and then giving an over supply of fuel; or in removing all the ash and clinker at one time, then trying to feed in evenly by hand instead of running the stoker engine a little faster. Of course, where coal is very moist over one grate and dry on another (a condition that sometimes exists), it will feed irregularly. In such case, however, by changing the links or removing them entirely for a moment from the dry coal side, and running the stoker a little faster, will balance the supply.

It is almost needless for me to state, that I believe (from numerous reports given out regarding the conditions of the various power plants of Chicago), that the Murphy stoker is equal to any on the market, as an economical, smokeless furnace, all conditions, of draft, capacity and fuel being taken into consideration.

I might state in closing that one excellent feature of the Murphy furnace, is the opening in front, whereby the industrious and careful fireman is able to see the conditions as they actually exist, and is thereby able to set aright, at once, any irregularities that may come up through changes in power, fuel, etc.

*Mr. W. L. Goddard*—(International Harvester Co.)—The part of Mr. Bement's paper which interests me most is wherein he justly places most of the blame upon the manufacturer, the consulting engineer and the architect, rather than upon the operator of apparatus. Many of the so-called smokeless "furnaces" on the market which very often are not furnaces at all, are gotten up to meet certain conditions and grades of fuel, and while satisfactory for the purposes intended, under other circumstances and fuel, are frequently most dismal failures, simply because the manufacturer was more intent upon making a sale than upon the suppression of smoke, and did not sufficiently enter into a proper consideration of details.

A large plant in New York now under course of erection, is putting in flat grates and will be fired by hand. An official of this company told me there was no stoker on the market that would successfully handle the grade of fuel they proposed burning, and they had studied all conditions.

The consulting engineer and architect are often to blame for many of the smoke producers. In fact, many of the smoke makers of our own and other cities are entirely due to the utter ignorance of such advisors of this important subject. I know of a large plant, erected not long ago, where the architect and consulting engineer were given *carte blanche* to produce the best possible; no expense was to be spared, and yet this plant is notorious as a smoker; all they contrived to give the man who paid the bills, was a stoker with

a boiler over the top of it; no attempt was made towards a furnace; the tubes of the boiler are but a few inches from the fire at the back end, and but thirty inches at the front. Is it any wonder that plant smokes? Yet this architect and consulting engineer are high up in their professions; they charge you an enormous fee if you consult them, and would be very much insulted if you told them they were ignorant of the first principles governing good combustion. Whenever this plant is referred to them, they blame the operating engineer for all of its shortcomings.

This brings us to the matter of the operation of the steam making apparatus, which, of course, includes the furnace. Much depends upon the personal equation in the fire room. The most expensive part of the steam producing element is almost invariably placed in charge of the poorest paid man about the plant, the fireman. His is a hard, dirty job and nobody wants it who can earn a living in any other way. I fired in a steamship for six months, at one time of my life, and it was hard work, hard fare, hard words; I got away from it as soon as I could and have never had any desire to return. Where the most intelligence is needed about a steam plant, the least is provided. The pay of the average fireman is not enough to attract a brainy class of men; the work is hard, hot and dirty, and the men who engage in it are strong of back rather than of brain, and yet here is where the most brain is needed. A fireman can waste more money than an engine with improperly set valves. An engine needs very little attention compared to a furnace. Possibly, if more money were paid the firemen, it would attract a better class of men and better results would be obtained. At one time I tried the experiment of hiring inexperienced men for the fire room, insisting only that they have a high school education. The scheme worked beautifully at the start; they had nothing to unlearn, and being educated, could be made to understand the chemistry of combustion and the rules for the economical burning of fuel. But alas for my dreams; as they made good firemen, they had ambitions to become engineers, and as the company would not discriminate between a good and a poor firemen as regards wages, inside of a year they were gone, and I had to content myself with anyone who could shovel coal.

Not long ago I had a night fireman call me out about 3 A. M., over a trivial matter. After I had straightened it out for him. I remarked that he might have gotten himself out of his difficulty without sending for me. His reply was, that if he knew as much as all that came to, he would be a chief engineer and not a fireman.

Much can sometimes be done by giving the men in the fire room an inducement to bring about good results. I was in a large power plant in New York, not long ago, which had a recording gas analysis meter on each boiler. The fire room was in charge of a well-paid engineer at all times. He watched the gas meter as he did the steam gauge; by signals he notified his men when to open or close

dampers and perform other operations. The engineer of the station told me that they gave a bonus to the watch who produced the best $CO_2$ reading for the month. He handed me a large stack of cards which I averaged up, and they showed 14 per cent. $CO_2$. Is it any wonder that firemen under this engineer had a direct interest in bringing about such results?

I was at one time employed by a company who made flour. The plant was so arranged that we could weigh our fuel. The mill ran night and day with three shifts of men; the company gave a bonus to the shift which made the most flour for the least amount of fuel. The men soon learned to fire properly, and under the stimulus of the expected bonus, a remarkably clean stack was the result. The same effect was produced in the case where the bonus was given for the best flue gas analysis.

In one of our departments we manufacture twine, composed of manila hemp and sisal. There is approximately 10 per cent. waste which contains about 12,000 B. t. u. per pound running very nearly 60 per cent. of volatile matter, and in the process has about 10 per cent. of oil added to it. One could not imagine a worse mixture for the production of smoke. Our plant originally was of the B. & W. type of boilers with vertical baffles and

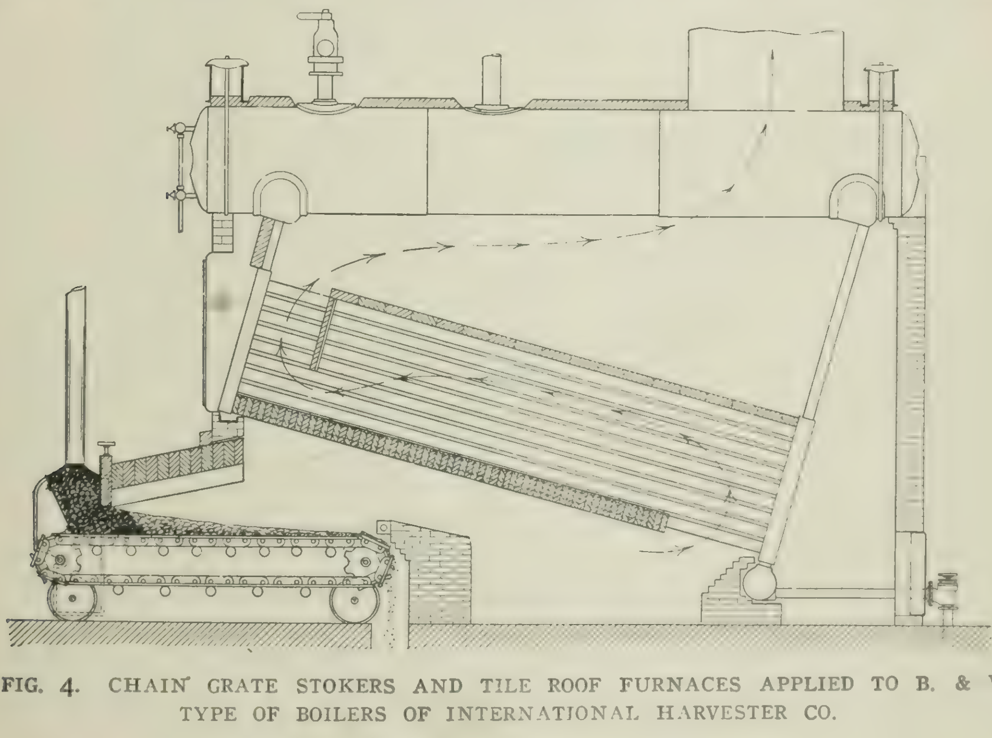


FIG. 4. CHAIN GRATE STOKERS AND TILE ROOF FURNACES APPLIED TO B. & W. TYPE OF BOILERS OF INTERNATIONAL HARVESTER CO.

chain grate stokers. The boilers were set very close to the grates and as this fuel was pushed in with a hoe almost as soon as it was ignited, the flame was among the tubes, which suppressed any combustion that had started. We were fined a number of times for making smoke, and eventually concluded that something must be

done. We first tried steam jets, but instead of stopping the smoke, they only increased it. This made it necessary to try something else. Finally we decided that the only way to burn this fuel was by means of a Dutch oven, but as it was impossible to put it in front of the furnace, therefore it was located under the boiler. This was accomplished by covering the lower row of tubes with tiles. The shape of the tiles first made, was such that we experienced trouble by their breaking off, until finally there was nothing left of

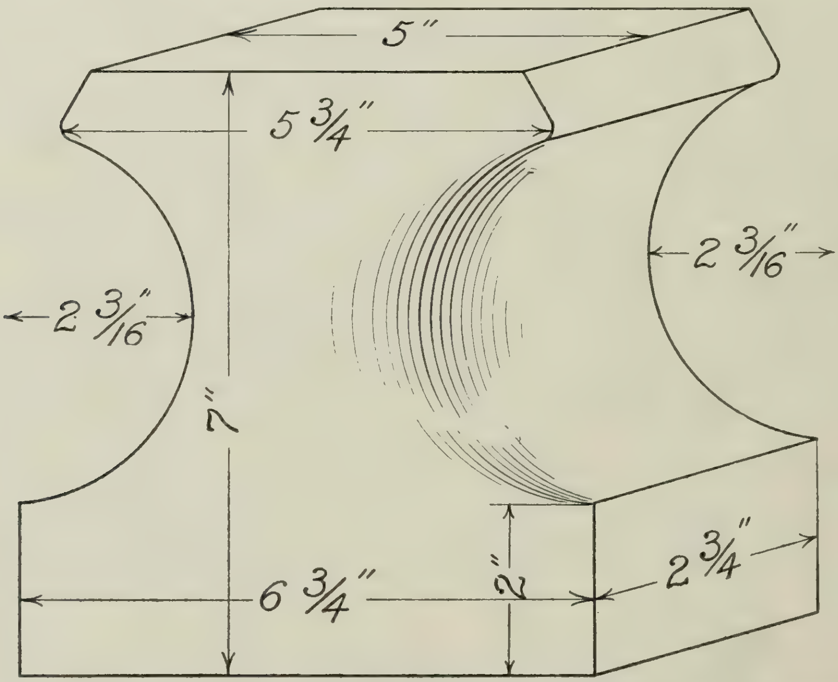



FIG. 5. "B. & W." FURNACE ROOF TILE USED IN APPLICATION ILLUSTRATED BY FIG. 4.

them except what laid over the top of the tubes, which exposed the lower half of the tube to the flame. The object of putting in the tiles was to produce, as nearly as possible, a Dutch oven. We had 3 feet of arch and 16 feet of tile, which gave us a Dutch oven 19 feet long. We took out the vertical baffles of the boilers and changed the travel of gases as shown by Fig. 4.

The new tile which we devised is shown by Fig. 5. It required 1,500 of this style tiles, costing 3½ cents each, to cover the bottom row of tubes. Their application to the tubes is shown by Fig. 6. The sectional view, Fig. 7, is a detail of the tile roof formed by their application to the bottom row of tubes. This effectually stopped the smoke when burning this waste product, and we obtained such good results that we applied a furnace to another boiler with which we were equipped for weighing the water and coal, and obtained some very extraordinary results. With this furnace and type of baffling we could evaporate, with the same grade of fuel, 14 per cent. more water than with the vertical baffling without

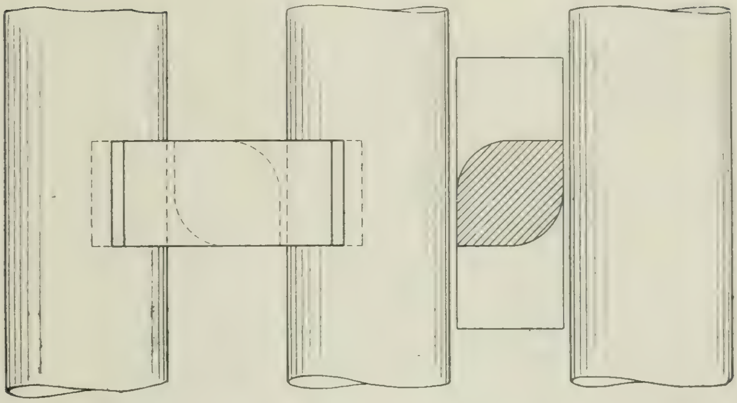


FIG. 6. PLAN SHOWING METHOD OF INSERTING "B. & W." TILE FOR FURNACE ROOF.

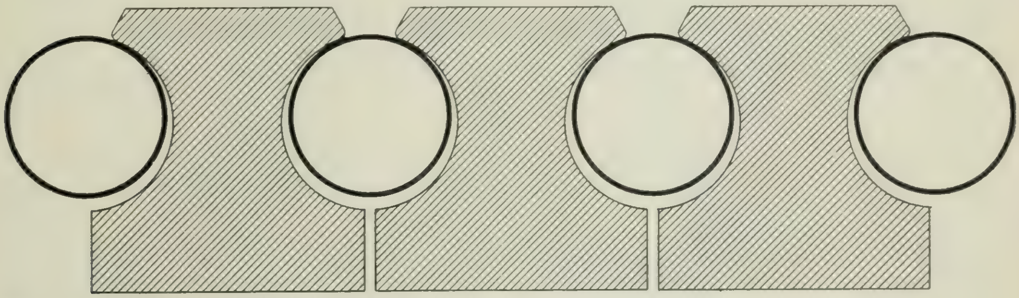


FIG. 7. DETAIL OF TILE FURNACE ROOF COMPOSED OF TILES ILLUSTRATED BY FIG. 5.

tiles. In the old B. & W. arrangement the highest $CO_2$ we could get under the best conditions was 8 per cent. With our improved scheme, we obtained gas samples with all the way from 13 to 17 per cent. $CO_2$, and by taking samples every 10 minutes for eight hours, secured an average of a little over 14.10 per cent. We first took the samples by the econometer, and the showing ran so high that we thought the apparatus must be out of order. Then we called in an expert, and the results he produced were even better than the reading of the econometer.

*Mr. Abbott*—I will call on another Engineer who has given this matter a great deal of study, and has done something along the furnace line which is very successful and promising,—Mr. A. J Saxe, Chief Engineer of the Railway Exchange Building.

*Mr. A. J. Saxe*—We had occasion not very long ago to install a new boiler plant in the Stratford Hotel. I had charge of the work. In the old plant there were four return tubular boilers, with flat grates and hand-fired furnaces, which were always bad smokers. As you know, this building is located on the corner of Michigan Avenue and Jackson Boulevard, on the lake front, where great care has to be taken to avoid making smoke; so in putting in the new plant the owner of the hotel told me to put in a furnace that would not make smoke, even if I had to sacrifice in economy. We had only 12 feet in width in the boiler room to get in a 600-H. P. plant, so we had to select a boiler which was rather high in order to get

the required power in that small space. We chose a horizontal Cahall water tube boiler, 12 tubes high. The boiler company would not guarantee a cast iron header boiler of this height, and one with steel headers would cost more than we cared to pay because the machinery and piping in the old plant not being able to stand more than 150 pounds steam pressure. Under these conditions we selected a boiler with cast iron headers of that type known as the double deck. This left a space in the center which we thought very desirable for a baffle, as we intended to baffle horizontally, instead of vertically, the usual way with this style of boiler. Placing the first baffle as we did (with an 8-ft. furnace arch in front) gave us a 22-ft. arch over the fire, a thing we most desired to get, leaving a 4-ft. opening for the first pass at the back end. Then we ran another one within three feet of the front end; then one back to within two and one-half feet of the back end, and placed the breeching connection at the front end, as shown by Figs. 8 and 9. This

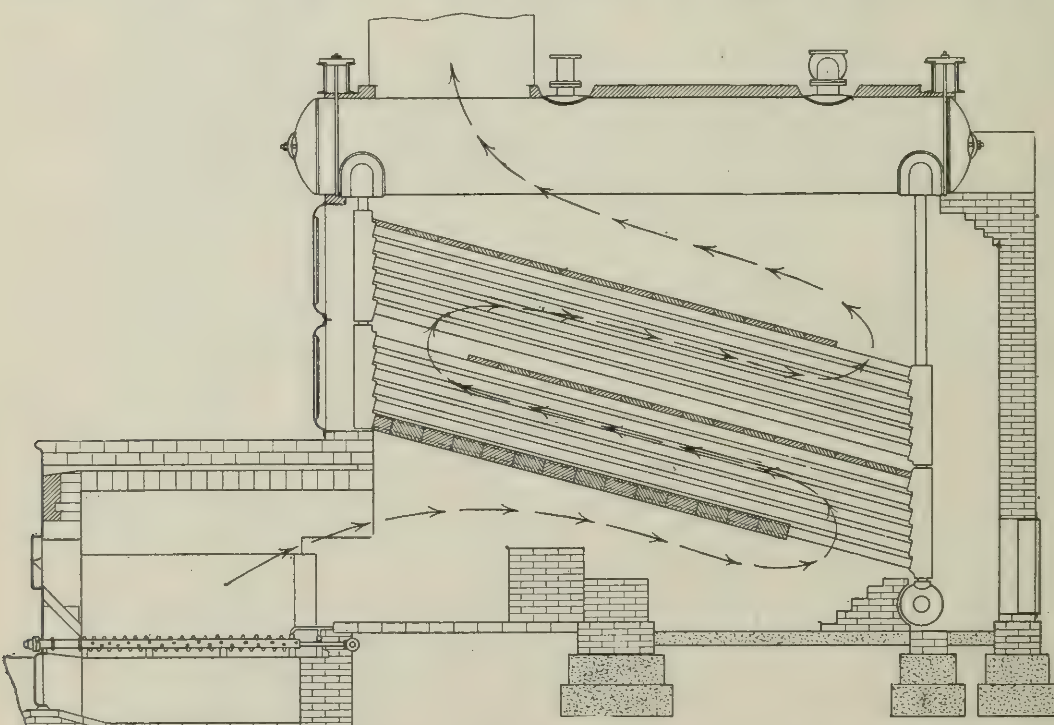


FIG. 8. MURPHY STOKER SERVING CAHALL HORIZONTALLY BAFFLED WATER TUBE BOILER WITH LONG TILE ROOF, IN STRATFORD HOTEL, CHICAGO.

put the heat four times through the boiler lengthwise, giving a 72-ft. gas travel through the heating surface of the boiler, and affording more time to extract the heat from the gases.

In talking the matter over with some interested parties before installing the plant, they said if we put the hot gases to the rear of the boiler first it would reverse the water circulation; so when we were ready to start up we attached cotton strings to the inside of the drums, with small weights on the ends. After running seve-

ral days, the boilers were shut down and the drums opened to see where the strings were; we found they were all as they should be, pointing to the back instead of the front, thus showing that the circulation was from the front to the back. The water carries

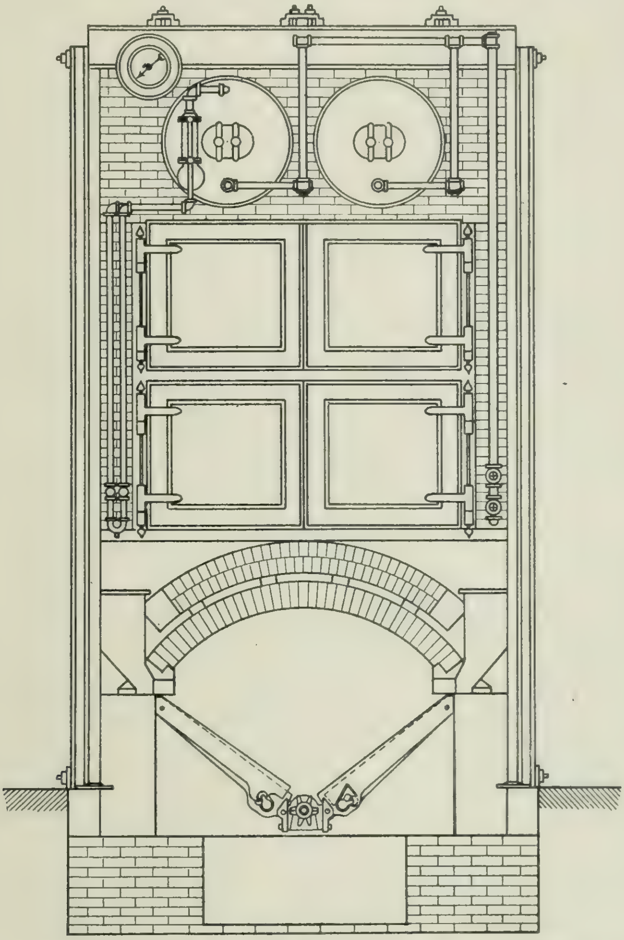


FIG. 9. ELEVATION OF BOILER AND FURNACE SHOWN IN FIG. 8.

very steadily in the boiler and we never have had any trouble with priming. When the furnace is properly handled, for weeks at a time, it does not make a particle of smoke.

The temperature of the furnace is very high. We had no way of measuring it, but when crowded it is perfectly white, like an arc lamp. We have a bridge wall in the back which was made of fire bricks that were guaranteed to stand a temperature of 3,200°. Fahr., and we melted them all together. A thermometer hung down between the drums from the top where the gases leave the boiler, at this time, with 150 pounds pressure of steam showed 387° Fahr. I think you will agree with me that this is a very low up-take temperature for such a high furnace temperature. The steam temperature at 150 pounds pressure is about 362° Fahr. This makes only 25° difference between the flue gas temperature and the steam temperature.

In another plant that I am familiar with I have seen gases burn with a blue flame at the back of the boiler after passing through all the heating surface, the heat going off up the stack instead of into the boiler as it should. At the Stratford Hotel all the combustible matter in the gases is consumed before striking the heating surfaces of the boiler.

It is surprising how much coal can be burned per ft. of grate surface with a very low draft in a tile-lined furnace like this, after the temperature is once up. We had the draft down as low at 0.17 in. and burned as high as 28 lbs. of coal per sq. ft. of grate surface per hour without smoke.

At the time the test was made, samples of the flue gases were taken at intervals of every thirty minutes. Some of them showed as high at 17.3 per cent. $CO_2$, which was almost perfect combustion. The average was 15.4 per cent. $CO_2$, which is unusually good.

There is always a vast amount of rubbish about hotels, which has to be gotten rid of; for this purpose a stoker without a door is not desirable. With the Dutch oven type, with a large door in front one can burn almost anything that comes along, as we do.

Another thing we have found very good about this style of a furnace for small plants, where only one large boiler has to be used to take care of the variable loads; that is, a 300-H.P. boiler for four or five hours in the evening may have to develop as much as 350-H. P., while during the rest of the twenty-four hours it may vary from 150 to 200 H. P. In most cases, this would make it very wasteful in regard to fuel, but with this style of a stoker having a V-shaped grate, it can be allowed to partly fill up with ashes and the stoker be run with reduced grate surface, which makes it fairly economical for light loads. Also, the fire can be increased from light to full load in a very short interval of time.

Few engineers realize the importance of having an air-tight boiler setting. Air should not be admitted anywhere except through the grates or proper openings provided for the same in the furnace. We have had some experience of this kind at the Stratford Hotel. When testing the flue gases we found those taken at the last pass through the boiler had about 5 per cent. more air than those taken at the first pass; and as all the flue-caps and set doors were sealed with stove cement, and there were no cracks in the brick work. we decided that is must filter directly through the 16-in. brick wall of the boiler setting. We covered all exposed brick work with ½-in. of asbestos cement, and pasted this over with one layer of canvas, and gave it two coats of paint. After this was done the gases were tested again, showing a difference of less than 1 per cent. between the first and last pass. The covering of the two boilers cost $194.00, and made a saving of about $100.00 per month on the coal bill.

The saving of coal with this boiler plant has been about 25 per cent. over the old plant of return tubular boilers, that we formerly

used; we have also added nearly 25 per cent. more demand for power of the plant in additional machinery.

*Mr. Carl Scholz*—(President Coal Valley Mining Co.)—Inasmuch as this is the first meeting of the Society I have had the pleasure of attending, I would prefer to listen rather than to talk, but since your Chairman has put me in the dual role of an offender, as a coal seller and coal user, it is only proper for me to say that both the coal and railroad companies which I represent, realize the importance of overcoming the smoke nuisance, and I desire to impress you with our willingness to do anything reasonable in that direction.

Believing that we would profit by the information collected by the City Club of Chicago on this subject, a meeting was recently held with the Smoke Committee of the club and several coal men, including myself, and I anticipate that the investigation now being made will bring about considerable relief. We realize that the presence of smoke affects three distinct classes. First, the operator or producer of coal; second, the buyer and consumer of the coal, and third, the people who neither produce nor burn coal in a commercial way.

The operator suffers if his coal makes more smoke than others. It is well known that the product of the western interior coal field, viz: Illinois and Indiana, has the reputation of producing more smoke than certain so-called "smokeless coals" mined in the New River and Pocahontas districts of West Virginia. When improperly fired, the western coals do produce more smoke, but it seems unfair that the operator in Illinois should be held accountable for something entirely beyond his control; yet this condition affects detrimentally, the sale of his coal.

The consumers are affected by the making of excessive black smoke, because every particle of smoke means a loss of power and money, aside from the fines that offenders are required to pay and the uncomfortable conditions which smoke and soot create.

Not having any interest in mines or in boiler plants, that part of the population whose interests are affected by smoke usually protest most vigorously, and there is no doubt but that stocks of merchandise depreciate and much extra expense is caused the population in a smoky city. In days past the smoky appearance of the cities was looked upon as a sign of industry and business, but in this advanced age, we aim to perform our work with clear chimney tops. It seems that Providence intended that smoke should serve as a sign of warning, since its occurrence indicates wastefulness and carelessness.

Believing that the sale of Illinois coal in this city has been detrimentally affected, especially since the strike during the early summer when the West Virginia mines were in continuous operation and since then on account of the more aggressive action of the city authorities, which movement has been misconstrued by the produc-

ers of so-called "smokeless coals" as indicating that the western coals were not desirable fuel, we desire to have the co-operation of this Society and others interested, in the solution of this question. We realize that the subject presents many difficulties, but I wish to offer a few suggestions which we, as producers, desire to bring to the attention of consumers. One of the main causes for smoke is the overcrowding of boilers. Frequently consumers would save much money by buying prepared sizes, costing a few cents more per ton, when the demand for power exceeds that normal to the size of the steam plant. This may be overcome by having the salesman visit the boiler room if he be capable of advising what kind of coal is best adapted for each plant. The larger companies may employ experts for this purpose, and we have this point under consideration. Another desirable method would be to have boiler makers prepare special designs of boiler setting adapted to the grade of coal to be used. It is a well known fact that larger boiler installations are of the most modern type; however, practically no changes have been made in the setting of the ordinary return tubular boiler, and the same kind of grates are furnished for the burning of the higher grade coals as are used for the cheapest coal, and yet this type of boiler is used to generate the major portion of power for the smaller plants. Aside from the saving which would benefit the cnsumer by extending the use of our native coals, we feel that having large amounts of money invested in the state and distributing great sums to our employes, a large portion of which finds its way to the business houses of this city, we are entitled to the fullest consideration and support in carrying out this move.

For the railroad company, I will say that experiments have been made with various appliances, and I believe that a considerble improvement has taken place. I am informed by the officials that the situation was improved greatly when the attention of offending firemen was drawn to their carelessness, and it may be the adoption of a premium system will help materially.

It is believed that the publication of a list of power plants creating too much smoke will bring about some beneficial rivalry, not only among the owners, but their operatives and also the producer of the coal. There is no doubt that mechanically fired boilers generally give better results, but since it is not feasible to equip all boilers with stokers, firemen should be required to fire more lightly and frequently.

*Mr. Abbott*—We have with us this evening a representative from the United States Geological Survey Fuel Testing plant at St. Louis. You know they have burned up a great deal of this country's coal and money in making tests upon this and similar subjects, and I will call upon Mr. Kreisinger to tell us something about that work.

*Mr. Kreisinger*—The Chairman stated that the man who sells the coal is somewhat responsible for the smoke which is made with

his coal. I think that the coal man is not to be blamed for any of the smoke, because he has to sell the coal as he mines it. The nature of the coal cannot be changed to make the coal burn smokelessly in any furnace. The thing which can be changed, in connection with the smoke problem, is the furnace. Any soft coal is smokeless, if burned in a suitable furnace, operated with proper care. Of the furnaces which will burn coal without smoke, the hand-fired furnace is the last one to be considered, because its successful operation depends largely upon the conscientiousness of the fireman. It is a great deal easier to avoid smoke in a chain grate furnace when there is plenty of combustion space, and a fire brick arch above the fuel bed. The chain grate feeds the coal into the furnace gradually and uniformly, and its successful operation is more independent of the constant attention of the fireman. In a furnace with fire brick roof and large combustion space it is possible to avoid smoke even with hand firing, but, as one speaker said before, it takes a first-class fireman to do the firing, and such men demand high wages. Generally, a man with a limited intelligence will not do the work as well as it can be done and thus smoke is produced. He may be taught a better method of firing, and he may use this improved method as long as he is watched, but as soon as the expert leaves the boiler room, the fireman will most likely go back to his old method, and make as much smoke as before.

*Mr. Abbott*—I will ask Mr. Kreisinger if the work of the Fuel Testing plant has been somewhat in the line of smoke abatement or whether it is directed toward fuel economy for determining the strength of coal.

*Mr. Kreisinger*—The work at the Coal Testing plant has been somewhat in the direction of smoke abatement, although the principal object of the work has been the determination of the value of different fuels for steaming purposes. Whenever we tested a soft coal we tried to eliminate the smoke. We have reduced the smoke 50 per cent. or more, and often we burn soft coal without smoke. We have a good fireman, and he is watched all the time. Our furnace has a fire clay tile roof with a smooth lower surface, and a large combustion chamber; it is equipped with a plain grate of 40 sq. ft. We fire about fifty pounds of coal at a time on one-half of the grate area, and every two or three minutes. The furnace has three fire doors and we fire alternately in the front of the first and the third doors and in the rear of the middle door at one time and then the rear of the first and the third doors, and the front of the middle door at the next time. In this manner the distilled volatile matter is divided into three streams and this division facilitates its mixing with the hot air coming from the uncovered portions of the fuel bed.

Another point in connection with the hand-fired furnace is that it is usually forced to burn more volatile matter than it was built for. We have often found that coal when burned slowly, say at

the rate of 20 pounds per square foot of grate area per hour, made no smoke at all. However, when the rate of combustion was increased to 26 pounds or more, smoke was produced, even though as great care was used in firing, and the firing was as frequent. This fact is in accordance with Mr. Bement's paper, where he states that the combustion space of a furnace is of a certain capacity, and that one should not try to burn more coal in it than the furnace was built for. The fact is that whenever a furnace is run above its capacity, it is bound to make smoke.

I have recently noticed an interesting fact, that with a chain grate stoker in a Heine boiler furnace, no smoke was made when the rate of combustion was 42 pounds. If the same coal were burned in a hand-fired Heine boiler furnace, smoke would probably be produced at the rate of combustion of 26 pounds. This seems to indicate that with the chain grate stoker more of the coal burns on the grate as fixed carbon and less of the combustible is driven off and burned as volatile matter, than is the case with a hand-fired furnace. This is probably due to the fact that with the chain grate stoker the coal is fed in gradually and is therefore, heated gradually, while with the hand firing, the coal is thrown on the top of the white-hot fire and is heated rapidly; this rapid heating is the cause of more combustible being distilled off as volatile matter and more smoke being produced.

In conclusion I will say that the hand-fired furnace should be the last one to be considered for burning smoke. In the first place it is rather expensive to operate, and the results are doubtful because too much dependence has to be placed on the fireman.

*Mr. E. H. Taylor*—(Fuel Engineering Co.)—Referring to Mr. Bement's paper, I wish to take exception to the clause in the last paragraph in which he states, "There is no one in Chicago prepared to take up this class of work," as the company with which I am connected make a specialty of this line of work and have been able to affect some substantial economies and to do a great deal towards the suppression of industrial smoke. I believe the suggestion that the work be taken up by the Engineering Experiment Station of the University of Illinois and the State Geological Survey, a good one. There is room, however, for much good work among our consulting and designing engineers, as they are much more available to the public at large for detail work on specific cases; that is what the purchaser and the smoke offender wants and needs.

I agree with what Mr. Bement says regarding the smoke inspection, but the remarks made by the representative of the City Club hardly have my approval, and while I heartily approve of any earnest effort toward smoke abatement, I think that the matter should be handled with reason. The ordinance might be made so strong that it would drive the manufacturers out of Chicago. I do not think that that is what we want. We have driven enough out of Chicago already. The manufacturers should be shown that smoke can be

stopped and that money can be saved by doing so. The average operator has been approached by so many different people with different smoke preventing devices and tried so many of them with failure in results, that he has become discouraged. This is due largely to the fact that many people when they find an idea that works all right in one place, try to spread it broadcast without considering that it isn't fitted for all conditions. It should be remembered that the element of time is necessary to accomplish anything in this line, and during the time while the consumer is doing all that he can to stop the smoke the plant should not be fined every day for making smoke, according to the idea of the City Club. That would certainly discourage the manufacturer from spending his money in an effort to try to stop smoke. I think we ought to encourage a man who wants to do what is right.

*Mr. Edwin Fitts*—(Murphy Iron Works.)—I am hardly prepared to discuss this question before a Society of this character, as it might be considered that I am doing so from a commercial standpoint, as a representative of a manufacturer of smokeless furnaces. However, I will endeavor to confine my remarks to the theory and not to the merits of the apparatus which I represent.

The theory of preventing smoke with the Murphy furnace is the same theory that Mr. Bement has brought forward in his paper and is based on the general theory of the combustion of bituminous coals.

When coal is introduced into a highly heated chamber, whether mechanically or by hand, it immediately begins to distill or give off its volatile matter. The portion of the coal thus given off burns as a gas and is what we are concerned with as regards smokeless combustion. This gas of distillation disassociates into fine particles of free carbon and gases having no carbon. In order to prevent smoke this free carbon must be burned while suspended, and in order to do this oxygen must be introduced to the chamber and be intimately associated with the carbon at a temperature above that of ignition. Here we have two conditions to fulfil: first, the thorough mixing of the gases of distillation with the air; and second, the maintaining of the mixture at a high temperature for a time sufficient for the carbon and oxygen to form a complete chemical combination.

In the Murphy furnace the entire grate area is covered with a fire brick roof and heated air is introduced above the bed of fuel, in such a manner as to obtain a thorough mixing of this air with the gases of distillation. This arrangement will produce smokeless combustion of bituminous coal and does not demand undue care on the part of the operator to obtain the same.

When this furnace is used in connection with the horizontal type of water tube boilers the principle of the combustion arch can be still further extended. This has been described by a previous speaker and is illustrated in Fig. 8.

The builder of a smokeless furnace must be able to adapt his furnace to any form of steam generator. In Fig. 10 is shown a Murphy furnace in connection with a well known type of water

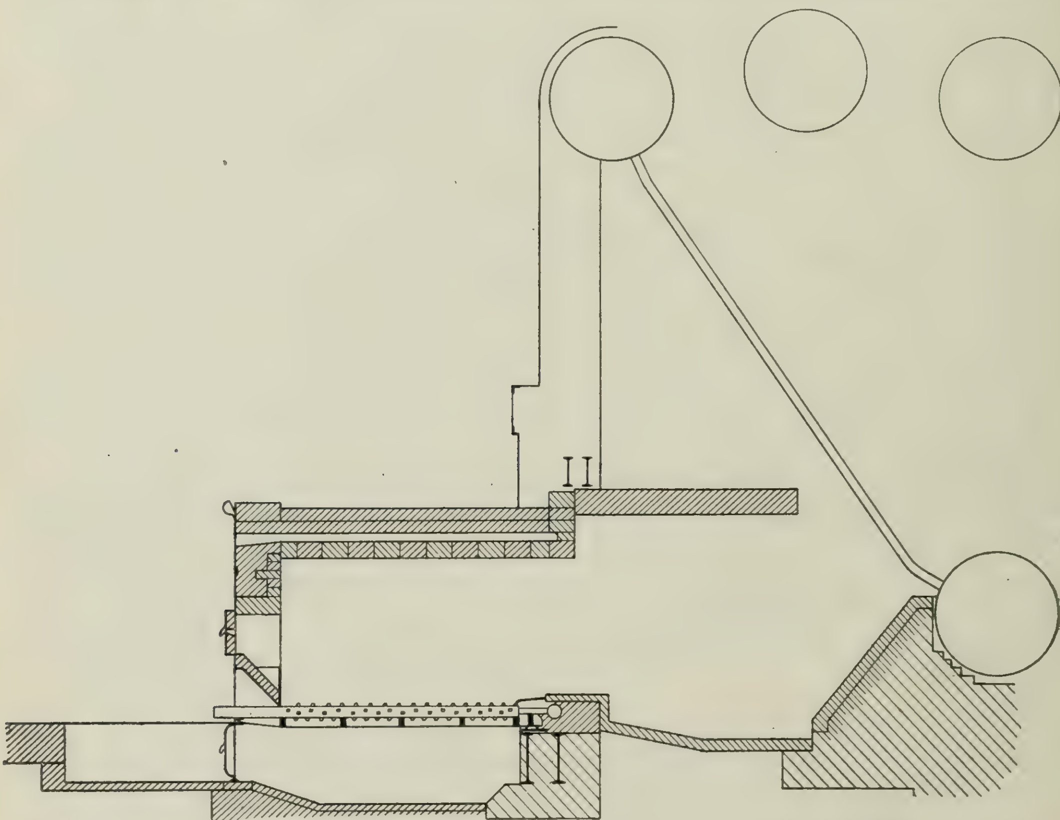



FIG. 10. MURPHY STOKER IN SERIES WITH ARCH OF STIRLING BOILER. OUTLINE DIAGRAM SHOWING NEW INSTALLATION FOR MARSHALL FIELD & COMPANY'S RETAIL STORE.

tube boiler which might be classed as semi-vertical. As has already been stated, the extended furnace and secondary arch are not necessary to produce smokeless combustion, but when a setting of this kind can be obtained it is without doubt the best from all points of consideration. Fig. 11 shows a Murphy stoker applied to a Heine boiler equipped with a tile roof, and in these various arrangements of grates and combustion chamber we have not only a smokeless furnace but a furnace capable of giving high economy and capacity, and that is also capable of meeting successfully any variation in demand for steam that the regular operation of the plant may bring about.

This will give you an outline of the theory of combustion as applied in the Dutch oven type of furnace. As I have already said it is the same that Mr. Bement has described in the paper of the evening.

A steam generator can well be divided into three parts: the grates or stoking mechanism, the furnace or chamber in which the combustion takes place, and the boiler. In a discussion of smoke pre-

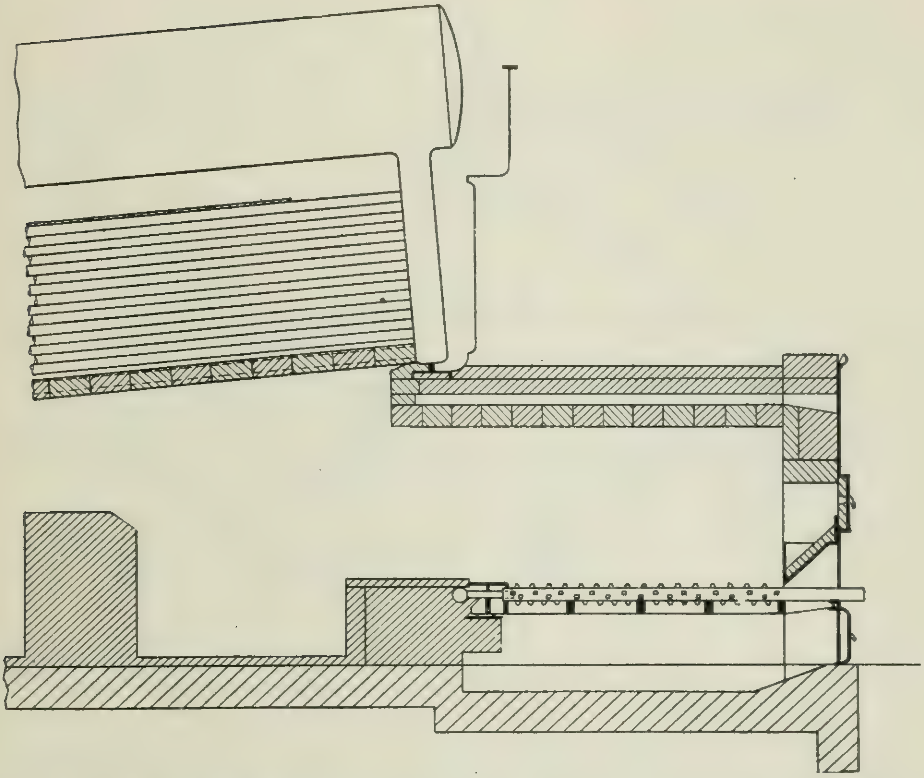


FIG. II. MURPHY STOKER WITH TILE ROOF FURNACE AND HEINE BOILERS, TO BE ERECTED AT THE AUDITORIUM HOTEL, CHICAGO.

vention we have to do with the furnace and so I have said nothing about the grates or stoking mechanism, as this would bring in matters foreign to the subject of the evening and would necessarily be at issue with statements in Mr. Bement's paper.

*Mr. Joseph Harrington*—Since Mr. Bement and others have referred more particularly to the chain grate stokers, I feel at liberty to make a few remarks along that line. I will confine myself to a few figures which I think may be of interest to you. We have a number of installations in Chicago, and the greater part of them are entirely smokeless or nearly so. We have recently been going more and more into the idea of the long arch. In a great many cases, although under old boilers, it is impossible to get as much arch effect as we want, so we have to approximate as nearly as we can.

Referring to the burning of sisal refuse. At the International Harvester Company-plant (Deering works), we have an installation where they are burning that on two furnaces, and although it is a highly volatile and very smoky fuel, the combustion is practically smokeless. We have a 5-ft.-long igniting arch with a water cooled gate to prevent the gate from burning out. In a recent installation in St. Louis, where we have a vertical pass boiler of the B. & W. type, we put in a 5-ft.-long sloping arch with 4 in. to the ft. rise, and a chain grate stoker placed as shown in Fig. 12. With

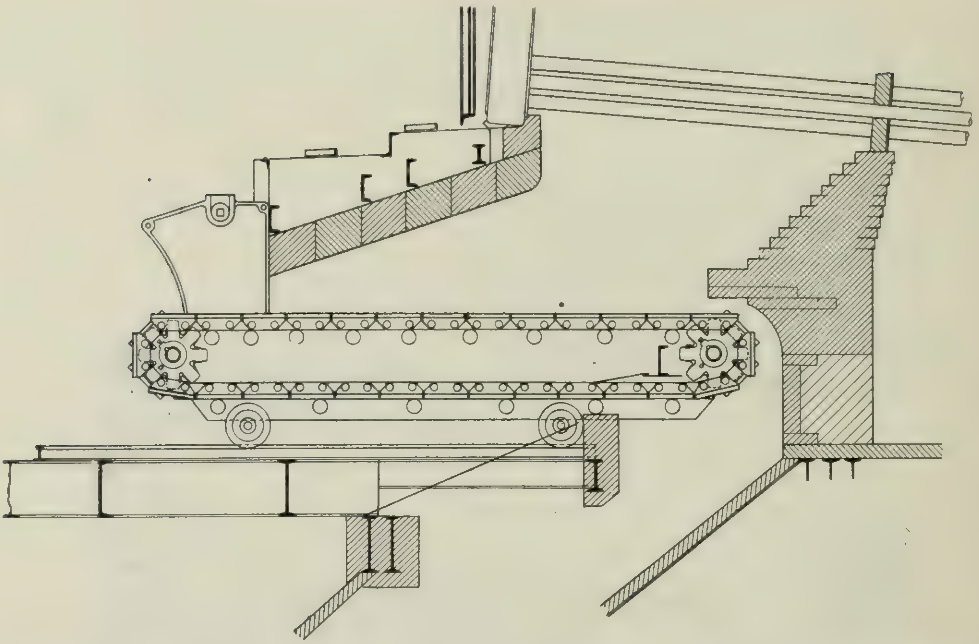


FIG. 12. CHAIN GRATE STOKER WITH LONG SLOPING ARCH UNDER EDGE MOOR BOILERS IN UNION ELECTRIC LIGHT & POWER CO., ST. LOUIS.

a 39 per cent. of volatile, Marysville coal, this gives perfect smokelessness. We burn this coal with about 0.25 in. to 0.3 in. of draft and run in a 6-in. bed of fuel. There are six 518-H. P. boilers to one stack, and when they are all going, there is practically no smoke.

In a somewhat similar installation in Birmingham, but under very different operating conditions, we have a B. & W. type of boiler, under which we are burning a coal with 28 per cent. of volatile. This stoker is in a Dutch oven entirely forward of the boiler proper. It is not possible with this coal to get the flame beyond the first row of tubes in the first pass and naturally the installation is absolutely smokeless.

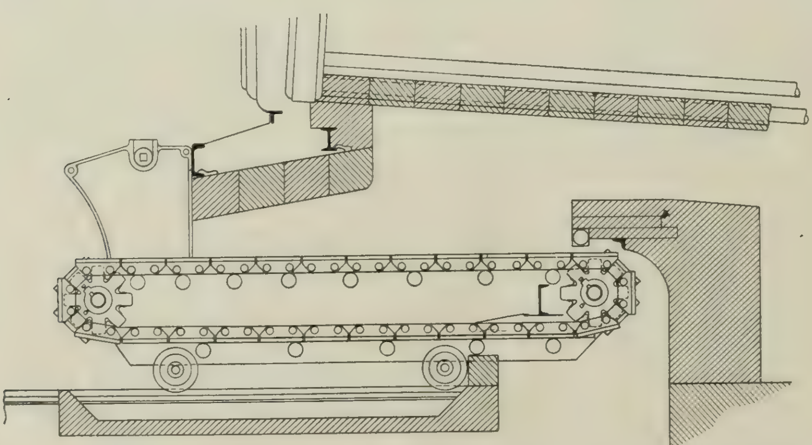


FIG. 13. CHAIN GRATE STOKER IN TILE ROOF FURNACE UNDER HEINE BOILERS FOR NEW COOK COUNTY COURT HOUSE, CHICAGO.

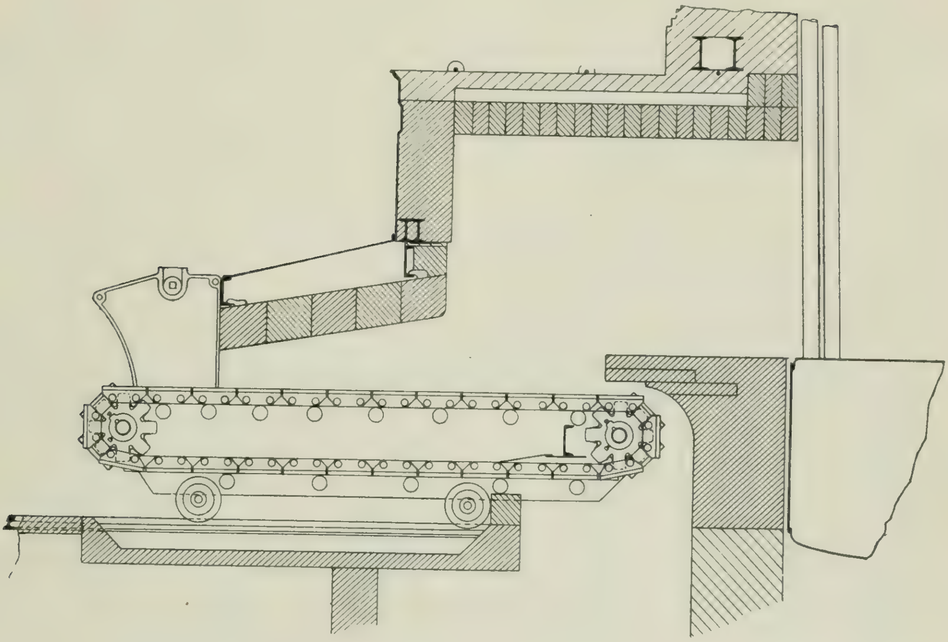


FIG. 14. CHAIN GRATE STOKER IN "DUTCH OVEN" SERVING VERTICAL BOILERS.

The Stirling boiler is a practically smokeless boiler when set in the usual manner with a chain grate. It has an excellent combustion chamber. The arch arrangement is very different, but serves the same purpose. We always put in a 3 ft. 6 in. arch, and even with such an arch it makes a smokeless furnace, owing to the fact that the Stirling arch is a practical continuation of the igniting arch and is anywhere from 4 ft. to 6 ft. long itself.

The Heine type of boiler, Fig. 13, with which you are all familiar, is another boiler with which it is comparatively easy to get smokelessness. The tube tile extend a good many feet back and as a rule the flame is entirely consumed. Fig. 14 shows application to a vertical boiler.

We are burning in a great many cases southern Illinois coal, which, under ordinary cases, is extremely smoky. We can get more smokeless coal as we approach the east; the Pittsburg coal will run as low as 30 per cent. volatile, and the coals from Birmingham will go down below 30 per cent. and the flame is extremely short.

In general, it may be stated that where we can obtain sufficient room to install the proper igniting arches and obtain sufficient room for a combustion chamber in connection with chain grates, practical smokelessness would be readily obtained.

*Mr. O. V. Bean*—(U. S. Smokeless Furnace Co.)—There is no need of any individual or firm paying fines for violating the smoke ordinance of any city, however strict, and especially is this the case in the city of Chicago, where the smoke ordinance is so very liberal.

Chicago might make her smoke ordinance more than doubly as exacting than it now is without working a hardship on her manu-

factories and power plants, and so save hundreds of thousands of dollars annually to her merchants in fewer smoke-ruined goods, and improve the general health of her citizens as well.

Any kind of bituminous (soft) coal may be burned in the heart of any city without giving off offensive smoke from stacks and with great economy in fuel.

The day of the "smoke consumer" has passed, and the day of the "smokeless furnace," producing perfect combustion on Nature's own simple plan, has arrived.

Any furnace to be of practical and commercial value in this day must be possessed of many virtues:

(a) It must be of simple fire brick construction without mechanical apparatus which readily gets out of order or with arches which are constantly falling down.

(b) It must adapt itself readily to any type of boiler and automatic, self-feeding stoker or chain grate when necessary.

(c) It must eliminate smoke and at the same time reward customers in money saved for so doing.

(d) It must not depend upon expert firing for results, but must be practically "fool proof;" for, even good firemen (who are seldom overpaid), cannot be depended upon to fire according to instructions.

(e) It must produce practically the same results when the boilers are forced 50 per cent above, or are reduced to 50 per cent. below their normal capacity.

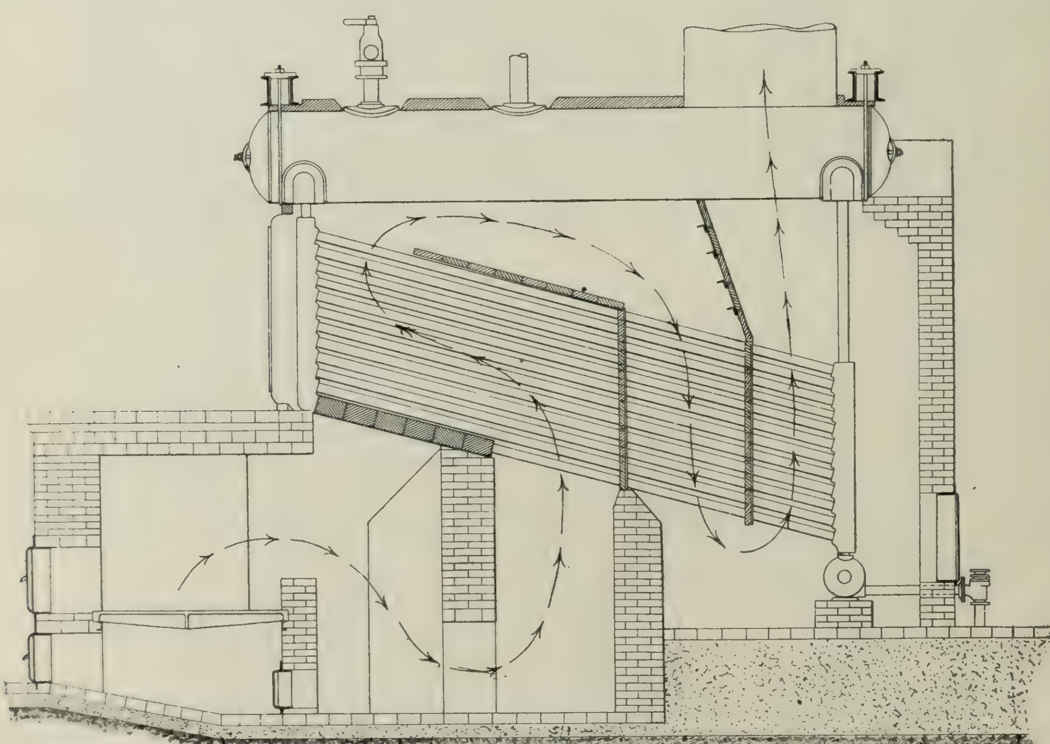


FIG. 17. ELEVATION SHOWING WOOLLEY FURNACE UNDER WATER TUBE BOILER.

(f) It must make it possible for the company exploiting the furnace commercially to pay all fines of customers for violating smoke ordinances, and to take the charge for installation out of the saving in fuel for one year or less if need be.

(g) It must last as long as the natural life of the fire brick used in its building without repair.

The Woolley Smokeless furnace, shown by Figs. 17 to 20, consists primarily of a dividing wall in the fire-box (in the case of two or more fire doors), supported on inclined or V-shaped grates, in order not to sacrifice grate surface, the side grates extending

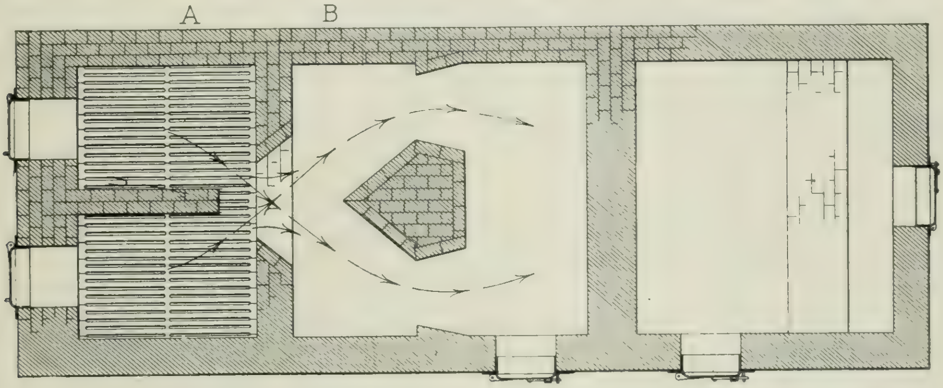



FIG. 18. PLAN OF WOOLLEY FURNACE SHOWN IN FIG. 17.

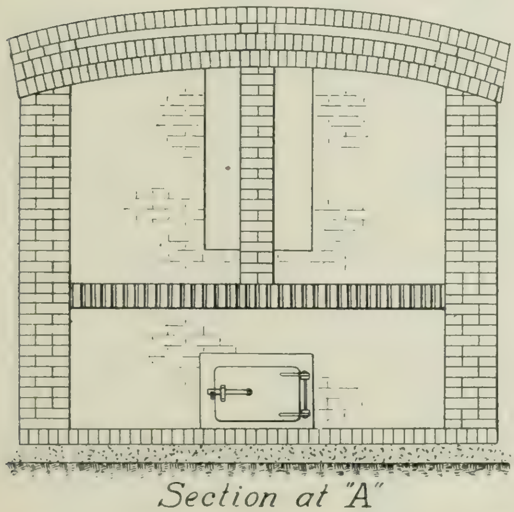



FIG. 19. SECTION OF WOOLLEY FURNACE AS INDICATED IN PLAN FIG. 18.

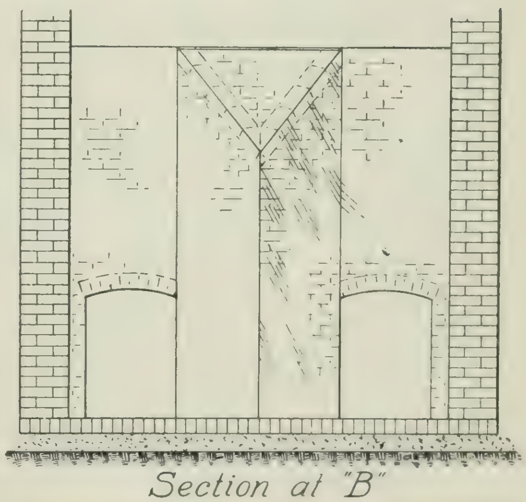



FIG. 20. SECTION OF WOOLLEY FURNACE AS INDICATED IN PLAN FIG. 18.

along the side walls also, to the depth of the fire carried; this center wall permitting of the alternate method of firing, whereby one side of the fire-box is always in an incandescent state, while the other side is being supplied with fresh fuel. Where stokers or other mechanical devices for supplying fuel are used, this dividing wall in the fire-box is omitted, but is used to regulate and improve the method of firing by hand, though it is not an essential feature of the furnace.

Theoretically, the furnace should be fired alternately (though this is not necessary), that the air and gases from one side of the fire-box meet the free carbon from the other side of the fire-box in the slot in the center of the primary bridge wall, where they unite and come in contact with a V-shaped masonry formation, having deflecting surfaces, laterally and vertically, and which act to retard and mix the gases and free carbon before they enter the regenerative or secondary combustion chamber. In this secondary incandescent chamber, combustion is finally completed before the gases come in contact with the cold tubes or boiler surface.

*Mr. Abbott*—Without any disrespect to the speakers who have already taken part in the discussion, I intentionally saved the best of the wine to the last of the feast. We have with us the Smoke Inspector of the City of Chicago, whose very efficient work in his department is giving us an administration for which we need not apologize. I refer to Mr. John C. Schubert.

*Mr. John C. Schubert*—My work, as you know, has been entirely in the line of smoke suppression. Every effort is directed toward the accomplishment of this purpose. Up to a few years ago smoke suppression met with many difficulties, and, to my notion, seemed nearly a farce. Little success was had under the old ordinance; few were in favor and many were opposed to its operation. Three years ago a decidedly different, and to my idea, more adequate, ordinance was adopted. The Department for the Inspection of Steam Boilers and Steam Plants was created, the Board of Inspectors being composed of the Chief Boiler Inspector, the Supervising Mechanical Engineer and the Chief Smoke Inspector Up to that time the Steam Boiler Inspection Department was a department of its own. There was no supervising engineer and the smoke inspection was done under the supervision of the Health Department. By the adoption of the ordinance of 1903, a new position was created, that of supervising engineer. The creation of this position was the strongest point of the new ordinance. Under this ordinance no new boiler plant can be installed or an old one reconstructed without a permit for such installation from the department. This permit is only granted after an application made to the department has been carefully gone over by the supervising engineer, as to the capacity of the boiler plant to do the work expected, stack area, breeching, smoke connections and smoke preventing device, the fuel to be used, and the size of the boiler room, so that the boiler and furnaces may be properly handled. It pleases me to say that new boiler plants installed under the provisions of this ordinance have caused but little complaint as to smoke.

I agree with Mr. Bement when he says that in many instances not sufficient attention has been given to boiler rooms by engineers. I could tell you of many experiences had by members of this board on visits to boiler plants. Mentioning one in particular, Mr. Wil-

cox and myself were asked to look at a certain boiler plant. When we arrived, and after an introduction to the engineer, with the proprietor of the plant we went to the boiler room. We found the fireman stoking the fire. When he got through we expected he would turn on the steam jets with which the furnaces were equipped. Not so, however; he walked away. Upon being called back and asked why he was not using the jets after firing, he replied, "They make too much noise." Next we found the 2-in. thimbles, cut through the boiler front over the fire door to admit air, plugged up with paper. When the engineer was asked why this was so, he merely answered, "That's the way I found them when I came here." In this case a number of fines had been imposed on the owners, and in defending themselves in court they swore that they had the best kind of smoke preventing device and were doing all in their power to prevent smoke.

For two years after the adoption of this ordinance, meetings of the board were held to help violators of the ordinance in securing abatements. These meetings were held Monday and Friday afternoons. Usually four different plants were investigated. The owner as well as the engineer of a plant was asked to attend at a certain hour. The engineer was requested to give a full and detailed statement of the plant in his charge. After hearing these statements the board advised what, in its opinion, would prevent violations of the smoke ordinance. These two years were really devoted to instructing and educating those operating offending stacks, and much was accomplished in this direction.

After two years' trial of the smoke provisions of the ordinance it was found difficult to realize the desired results. So early in this year an amendment to the smoke provision of the ordinance was made, and consequently much better results have been obtained than formerly.

The smoke ordinance works no hardship on any one operating a steam plant; it is a lenient one, and when owners and operators make any kind of an honest effort, can be complied with. At times the department is criticised for what some believe is a too strict enforcement of the ordinance. To those I wish to say: The activity in smoke prevention has created a new profession, as mentioned by a previous speaker. Owners of large steam plants have found it profitable to engage efficient mechanical engineers to locate causes for smoke, to suggest what would be the best way to avoid violations and to demonstrate the most economical way of operating their plants by testing fuel, drafts, etc.

As said before, the department has been criticised either for enforcing the ordinance too strictly or for leniency shown to smoke violators. Criticism is often made without knowledge of conditions. Let me cite an example: At a steam plant consisting of a battery of two boilers fully capable of doing the work required of them, and being managed so that no dense smoke is emitted from

the stack of the plant, the owner is compelled to shut down one of the boilers for repair, thus crowding the work on one boiler that is usually done by the battery—crowding it beyond its capacity. Dense smoke would naturally be the result. Is it fair under such conditions to prosecute the operator? I hardly think it would be right to prosecute when orders given by this department are being carried out.

When I came here this evening I did not know I was going to be called upon to speak on this subject. I am pleased to have been invited and that I came, for the different speeches made have been of much interest to me.

COMMUNICATED BY LETTER.

*Prof. Wm. Kent*—(Syracuse, N. Y.)—The statement that it is a recognized fact that bituminous coal can be burned without smoke is true as regard those who are well instructed on the subject, but there yet remains a vast amount of public ignorance on the matter.

In addition to the three classes of people who are to blame for the present condition, in Mr. Bement's opinion, namely, manufacturers of apparatus, consulting engineers and architects, and purchasers, we might add two other classes: first, the ignorant public who believe that a smoky atmosphere is the necessary condition of a Western city, and second, the careless public who are willing to live in dirt.

As to the requirements for smokeless combustion, I expressed them several years ago, as follows:

1. That the gases are distilled from the coal *slowly*.
2. That the gases when distilled are brought into intimate contact with a sufficient supply of *very hot* air.
3. That they are burned in a hot fire-brick chamber.
4. That while burning they are not allowed to come in contact with comparatively cool surfaces, such as the shell or tubes of a steam boiler; this means that the gases shall have sufficient space and time in which to burn before they are allowed to come in contact with the boiler surfaces.

Mr. Bement's statement of the requirements is in effect very nearly the same as mine.

His second statement, however, needs some explanation. What is a sufficient length of travel between the fire grate and the exit to the boiler to insure a thorough mixture of the volatile gases with the air? There is such a thing as stratification of gases, as anyone can be aware who notices the clouds in the sky or the escaping smoke from a chimney. A column of smoke and smoky gas may travel for five miles without being completely mixed with the air surrounding it. It is therefore necessary not only to have a long distance for the gases to travel in the furnace but also some means of mixing them, so as to prevent their stratification.

In the case of the construction shown in Mr. Bement's paper. the extended furnace in front of the boiler and the chain grate stoker with a fire brick combustion chamber are all excellent things in fact the whole construction is excellent as far as it goes, and it is undoubtedly a smokeless furnace when the rate of feeding and the supply of air are properly adjusted and when the air is so admitted as to cause it to mix with the volatile gases. No such means for mixing the air and the gas is shown in the drawing and there is a possibility that gas distilled from the thick bed of coal at the front end of the stoker may rise to the roof of the chamber and pass along it and enter the boiler without being burned, since the gas is lighter than the air and the carbon dioxide which enters the combustion chamber from the rear end of the grate. This condition may be remedied by having jets of air directed forcibly at right angles into the traveling mass of smoky gas which will cause the gas to mix with the hot air below it. Another means of causing the mixture would be to build in the rear of the combustion chamber about two feet behind the bridge wall a pair of the wing walls of my Wing

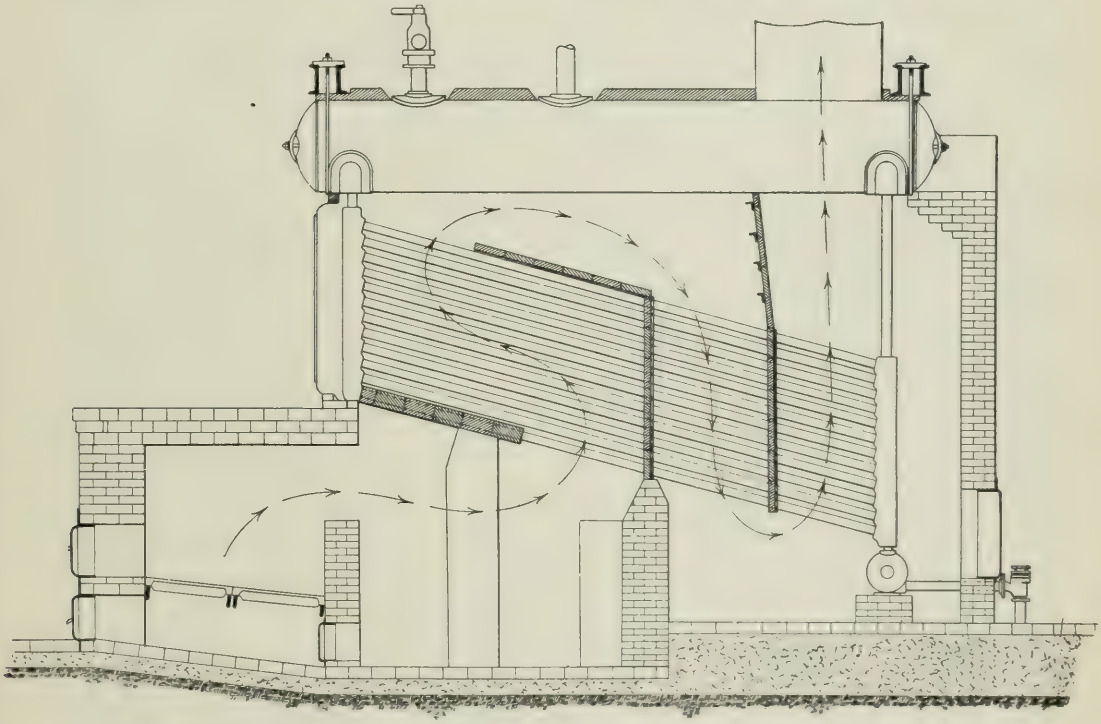


FIG. 15. ELEVATION SHOWING KENT'S WING WALL FURNACE.

Wall furnace, shown by Figs. 15 and 16, and patented May 17, 1898. The addition of the wing walls to Mr. Bement's construction would, I think, place it beyond criticism.

*Mr. J. J. Merrill*—As usual, Mr. Bement is "knocking" something, and his largest hammer is now applied to makers of furnaces and boilers, whom he appears to consider a bad lot generally,

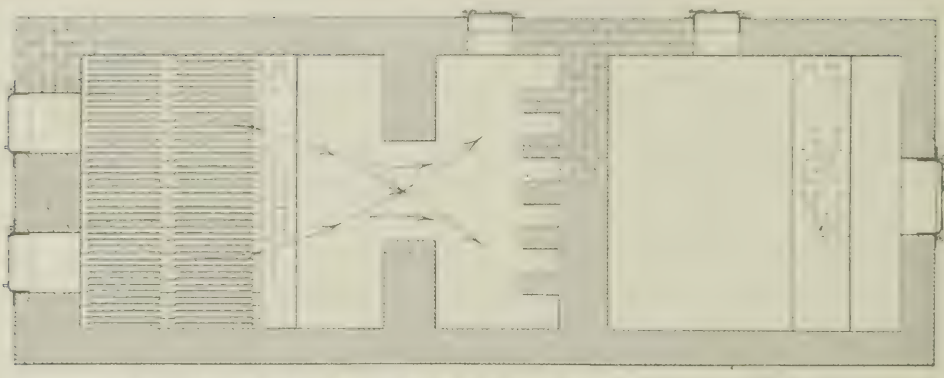


FIG. 16. PLAN SHOWING KENT'S WING WALL FURNACE.

while the purchaser is set on a pedestal as an example of innocence and virtue.

I have not written for the purpose of offering any defense for manufacturers; rather to make clear my own personal attitude toward furnace and boiler improvements, but would call attention to the fact, that if a manufacturer makes a change or improvement in his apparatus, he invites trouble for himself, because the purchaser is liable to blame the improvement for any accident or carelessness on the part of the men who operate the apparatus. For example: if the fireman neglects or fails to maintain steam pressure, he is liable to claim as an excuse, that the change in the apparatus rendered it impossible for steam to be made in sufficient amount. Then the proposition falls back on the maker, who is put to endless trouble for no just cause whatever. Under such conditions it is no wonder that makers are satisfied to stick to the old rut.

As a general rule, purchasers "get what is coming to them," and usually what they deserve, and they should not be excused on the plea of ignorance as Mr. Bement appears to intimate, because they have no just reason to be ignorant, and lack of knowledge should not be an influencing factor if proper effort was made to keep abreast of the times and use data which is already available.

Mr. Bement intimates that a purchaser cannot obtain improved apparatus such as he suggests, unless he demands it, yet I have sold Aultman & Taylor water tube boilers to the following people and in each case the tile furnace roof suggested by Mr. Bement, has been applied with my recommendation, and the installations have proven eminently successful. One of these plants is in the Stratford Hotel, corner Michigan and Jackson Boulevards, where two horizontal Aultman & Taylor boilers are served by Murphy furnaces, the tile roof extending back on the lower row of boiler tubes about 14 ft., so that, independent of the extension of the Murphy furnaces, the gases are compelled to travel these 14 ft. before they come in contact with the boilers at the rear end, from which point they come forward among the tubes of the lower deck to the front end, thence back among those of the upper deck, and finally forward under the drum to the exit, which is at the front

of the boilers rather than at the rear; thus the gases travel in contact with the heating surface on a horizontal rather than a vertical line. Mr. E. J. Saxe is responsible for this design, yet every feature of it had my approval and recommendation, although I do not as a general thing, approve of a horizontal travel of the gases, as I believe that a vertical travel at right angle to the tubes, breaks up the column of gases and distributes them more generally over the entire tube surface, thereby cooling them to a lower temperature than is possible with the horizontal travel, but the tile roof furnace so improves the furnace efficiency, that the loss due to the horizontal travel of the gases is more than offset.

In the case of similar boilers sold to the Western Cold Storage Co., to be fired by hand, I used this tile furnace roof scheme to avoid smoke, and the result is very satisfactory. In several other instances, however, I have not offered the tile roof for reasons already mentioned.

In the above cases the furnace roof was employed to prevent smoke, but having sold some large boilers recently, to be operated in the vicinity of New York city, the fuel to be anthracite coal, I have applied the tile furnace roof for the purpose of obtaining larger capacity than would be possible without it, because the higher temperature in the furnace chamber and at the fire, ensures that more coal will be burned without an increase in the draft.

This tile roof furnace scheme is bound to grow and become an important factor in improving conditions in the future; in fact, in the immediate present, and it will be useless for either manufacturer or purchaser to oppose it, because it is in harmony with certain natural laws, but I take issue with Mr. Bement regarding the opposition all coming from manufacturers, because there is fully as much on the part of the purchaser. I wish to state, however, that the tile roof is no hobby of mine, and that I would not use it if the same results could be obtained in any other manner.

*Mr. F. S. Peabody*—Mr. Bement appears to lay the burden of blame on manufacturers and consulting engineers. Not being an engineer, I am unable to decide whether or not he is correct in this, but it is a fact that bituminous coal of the poorest grades is burned in this city without producing smoke. There must be a reason for it, and no doubt furnaces are not always correctly designed, or else not properly operated, in view of the fact that there are still too many smoky chimneys.

The use of washed coal, which is rapidly increasing, has resulted in the elimination or reduction of smoke in a great many instances, and that grade known as No. 5 washed will in most cases produce no more smoke than eastern coals which command a much higher price.

I am interested in the operation of coal mines in other states than Illinois, but as a business man I would emphasize the importance of coal production as one of the greatest industries of this

state, and one which should be encouraged. There is a large amount of coal brought from other states, and for which the public pays a higher price, because it is believed to be less smoky than Illinois coal. The result is that a corresponding amount of business goes out of the state which would otherwise be held at home, and for this reason, if for no other, Illinois coal operators should render every pssible assistance to efforts toward smoke suppression. The Peabody Coal Company has made an extended study of furnace design and construction, and in the very near future, the result of its efforts will be published for the benefit of the public.

*Mr. E. B. Powell*—(New York Edison Co.)—I can thoroughly agree with all that Mr. Bement has to say, as relating to combustion of coal in the ordinary way—on a grate; and I am in hearty sympathy with his plea that a large share of blame for the existing more or less opaque condition of our skies rests with the designing engineers and boiler manufacturers.

As to the method of handling the so-called "bad" and "moderately good" installations: I should consider a campaign of enlightenment most promising of satisfactory results. Not merely should the firemen be instructed in the handling of his fuel, but the manager and the owner of the plant should be brought to recognize the importance from an economic point of view, of scientific treatment in boiler operation. Such a campaign would be very materially aided by the co-operation of state institutions of the standing of those mentioned by Mr. Bement.

The larger plants can well afford to retain an advisory staff of engineers, but for the benefit of the small steam user (although the community at large could not fail to feel the influence thereof), the organization of a society on lines similar to those of the "Society for the Management of Furnaces and Controlling of Smoke," of Hamburg, Germany, having for its object the diffusion of information, relevant to the subject, and the education and supervision of firemen, would be of great advantage.

I have recently been much interested in the development of an apparatus for the utilization of pulverized coal in steam generation; such an apparatus, could it be put upon a commercial basis of operation, would solve simultaneously both the problem of smoke abatement and that of boiler labor; incidentally, of course, the higher initial temperature, due to close approximation of actual air supply to that theoretically required, which it is possible to obtain when burning pulverized fuel, would result in a correspondingly higher thermal efficiency.

*Mr. W. J. Green*—(Cedar Rapids and Iowa City Ry. & L. Co.)—Mr. Bement's paper appeals very strongly to the writer. Had the money and energy which has been expended in experimenting with all kinds of smoke preventive devices been applied along lines suggested by Mr. Bement's paper, the smoke nuisance would, unquestionably, be largely abated by this time.

Cities, in addition to, or prior to, passing edicts that furnaces must stop smoking, might well give specifications describing apparatus that will be accepted as a sure prevention, and thus relieve the purchaser of great financial losses by making wrong selection or arrangement of apparatus.

The writer, as one under the third class, desires to emphasize the difficulties experienced by purchasers in enlisting the support, to say nothing of even a little encouragement, from manufacturers when asking for any rearrangement or change in apparatus. He recently had occasion to ask for bids on a steam generator under Mr. Bement's specifications. Numerous objections were immediately raised. None of the objections, however, seemed to possess any merit, when analyzed, unless it was the one general cry that, "We have been doing so for years, employ the very best engineers, and do not propose to make changes on suggestions from outside engineers." Then one manufacturer was willing to meet the specifications. Finally several broadened sufficiently, as a result of the demands from their agents, to be willing to furnish the apparatus, after predicting all kinds of failure and with the distinct understanding that they assume no responsibility whatever, except for workmanship and material.

It is not strange that progress in suppression of smoke has been unsatisfactory when the opposition of the manufacturer to applying such changes as have been demonstrated in general to be practical and effective, is so strong that purchasers are scared off from departing from the manufacturer's standard product.

*Mr. H. W. Woodward*—(First Asst. Engineer, City of Cleveland.)—I have read over very carefully the printed copy of Mr. Bement's paper. The illustration which Mr. Bement furnishes of boiler setting and chain grate stoker shows a combination which would undoubtedly admit of smokeless combustion. Conditions which Mr. Bement describe in his paper are ideal. Unfortunately these conditions do not exist in all power plants in practice.

In a good many places the last thing to be desired would be a continuous, uniform supply of fuel, for the reason that the demand on the boiler plant is neither continuous nor uniform. In very many plants with which we have come in contact, the load varies excessively and at irregular intervals.

In such plants as heavy rolling mills, electric welding establishments, packing houses, etc, the demand for steam is very irregular and changes in load are sudden. Other plants, such as street railway power houses, have very heavy peak loads which come on and drop off suddenly, though the time of the peak load is generally pretty well defined, yet it means frequently the putting into service and taking out of service a large number of boilers during the day's run.

In addition to steam boiler plants there are heating and annealing furnaces, stills, brick kilns, etc., to be dealt with. In these, the

requirements for fuel are such that a chain grate stoker with a uniform feed would not meet the conditions at all.

Thus, you see, while the ideal installation as described by Mr. Bement is very desirable when the conditions are right, yet there are very many cases with which the consulting engineer or smoke inspector has to deal where other forms of equipment are absolutely necessary.

*Mr. H. E. Horton*—(M. W. S. E)—Without doubt the question for any community like Chicago to decide whether they will have smoke or no smoke is an economic one. If we burn only anthracite coal or coke, we would not be annoyed with smoke. The cost would be for general purposes three times as much as bituminous coal, and while smoke is very offensive, we accept it for obvious reasons.

Mr. Bement suggests, "It is a recognized fact that bituminous coal can be burned without smoke." Right here is the issue. Is this statement borne out by any facts that anyone, anywhere, or in any way can verify? There has nothing developed for many years, excepting slightly varying mechanical details of the appliances offered to burn bituminous coal without smoke.

That the condition of average smoke can be developed is undoubtedly a fact. In the various discussions, the suggestion is made that "dense" smoke is the measure of all iniquity. We can readily observe dense smoke, while average smoke seems to escape common and average notice. Average smoke is to free say 1,000 units of smoke from a given quantity of bituminous coal in 1,000 seconds, one unit of smoke per second for the full time; while what occurs in the worse smoking plants is that say 10 units of smoke are freed for each of the first 100 seconds, thus giving the total volume of smoke in one-tenth the full time. This average smoke covers essentially all that has been accomplished in all the years of smoke prevention.

The subject has been one of much feeling and more discussion. The discussion is more psychological than physical as far as the investigation and argument has gone. Nothing has been attempted in the way of an accurate measure of smoke, more than the mere personal equation of the observer and this alone indicates the difficulty when the engineer attempts to approach the question because the engineer is supposed to deal with exact subject matter measurement rather than of feeling.

The suggestion of reference to the University for research would seem to be proper, the investigation discovering a way to measure smoke and then to determine the quantity produced from a given quantity of coal is surely desirable. The investigation to the present time has been approached quite in the same way and with the same argument that is made by those individuals who are attempting to square the circle, or develop perpetual motion. The one knows of his ability to square the circle because he desires to. The

gentleman of smoke prevention knows that smoke from bituminous coal can be prevented because he *wishes* it so emphatically. The gentleman promoting a perpetual motion appliance knows that it will work because it would be of such a vast advantage to all mankind. The gentleman with a special detail of method to burn bituminous coal without smoke knows he can accomplish results with equal certainty and advantage. It is all the same argument presented for squaring the circle, for perpetual motion, smoke prevention, and the argument is merely the fact that a thing desired must develop because "mind is superior to matter."

The City of Chicago did burn anthracite coal at the Chicago Avenue Pumping Station for 15 years; the neighbors could see the smoke of bituminous coal and they had a pull. The City of Chicago is today in all its pumping works burning bituminous coal with just the same movement of smoke there was there 50 years ago. The City of Chicago is also burning bituminous coal in its school houses, emitting a quantity and quality of smoke the same we are all familiar with. I do not believe there is any malice on the part of the City of Chicago in making smoke, neither do I believe that it is blind stupidity as it is often charged, but I do believe it is an economic condition.

The agitation here in Chicago has now extended over a long period of years and yet there is every reason to assert that the volume of smoke at first and at the present time is in exact proportion to the amount of bituminous coal burned in the municipality. It is not necessary that bituminous coal be burned for steam for such coal to make smoke. It will make smoke, plenty of it, if used for heating or cooking in the domestic or any other way.

The City of London, England, has an older civilization than ours and they use only bituminous coal. It is a current statement that in the days when our ancestry were hanging witches in Salem, Mass., the strenuous people of London were hanging men who made too much smoke, and still they continue to burn bituminous coal in London and there is no evidence to show that the proportions of smoke freed to coal burned has changed there in the past 300 years.

We, who only know of London by hearsay, are told of the London fogs (the mere settling down of smoke) and still London is the center of civilization of the earth. We of Chicago hope to rival London as a great center of civilization. If London finds it possible to endure the smoke, we can undoubtedly do the same. Quite recently London had a royal commission to do away with smoke and this commission reports the only way it may be done is for the municipality to construct conduits underneath the streets into which may be carried all products of combustion of all fires, passing the same through a water seal, quite in the same manner we are familiar with as to gas works.

Anthracite coal does not produce offensive smoke, neither does coke, only at the bee hive ovens. The by-product coke process

is an example of the way smoke may be eliminated, but unfortunately for Chicago the coals contiguous to her are not coking coals and as Chicago's future growth and development must turn almost entirely on its manufacturing industries, from the history of all that has gone before, we may reasonably conclude that we shall continue to burn bituminous coal in a goemetric increasing quantity and unless we find it feasible to condense smoke by passing through a water seal, that smoke will increase in the next 10 years by a much larger ratio than it has in the past 10 years.

The suggestion has been made that other communities are free of smoke, which has been true in a marked degree in New York City, where in years past anthracite coal was cheaper than bituminous coal to produce heat. Recently the conditions have changed and it takes no close observer to notice the increasing quantity of smoke in New York as compared with years ago, and with the marked advance in value of anthracite coal fully established as a luxury, we may yet expect to see New York our rival in smoke making and in due time having fogs equal to those of London.

Smoke is unquestionably an economic condition in Chicago. The amount of coal stored in the fields of Illinois is greater than any other state. It is contiguous to Chicago and Chicago's destiny undoubtedly is to be one of the great, if not greatest manufacturing center in the entire nation. This is not possible by any other method than with coal to produce the energy and it cannot be of the anthracite because the supply is limited. It cannot be of coke because we have discovered no method of coking local coals. It is only reasonable to expect that conduits will be provided by the municipality to actually care for the smoke when they have seriously approached the subject elsewhere.

No one desires the smoke we have, but we can endure it. Judging the future by the past, if Chicago is to establish and maintain itself as the great manufacturing center of the nation we shall undoubtedly have to accept with the advantages, the nuisance and disadvantage of bituminous coal smoke.

*Mr. R. S. Moss*—(M. W. S. E.)—Mr. Bement has given us a very interesting paper; the principles outlined regarding the combustion of coal, are undoubtedly correct. I agree with them that we certainly require better engineering practice in designing boiler plants, and it is unfortunate that consulting engineers are not better posted. At the same time, it seems to me that purchasers are to blame because they do not engage some recognized authority to go over the condition; the result would be that recommendations would be made from such an examination that would meet the particular case.

It is undoubtedly true that bituminous coal, regardless of the per cent of volatile matter, can be burned without smoke. I take exception to Mr. Bement when he says that with one possible

exception there are, strictly speaking, no smokeless apparatus made I think he will agree that exception must be taken to this wherever a case can be pointed out that is operated according to the principles of combustion.

The Underfeed Stoker System, undoubtedly meets the principles of perfect combustion, inasmuch as the incandescent mass of fixed carbon distills the volatile matter in the coal; this volatile matter must consequently pass up through the incandescent mass of carbon and is therefore raised to a sufficiently high temperature for ignition; then given a proper supply of air, delivered in a finally divided state, rapid and perfect combustion ensues. Of course, I recognize that one must not oxertax the mixing capacity of the furnace chamber, but the difference between chain grates and the Underfeed Stoker is the greater rapidity of combustion that takes place in the latter method as compared with the former. Then again, a chain grate does not give a proper proportion of air supply to meet the amount of coal that is on the grate, and while one may get a smokeless combustion by this method, it is rather due to the fact that we have got an excessive supply of air and therefore diluted combustible matter.

In conclusion, my suggestion would be that purchasers call in some recognized authority before deciding on any kind of stoker; if they would do this, they would get what is best suited to their conditions. Regarding the manufacturers of furnace apparatus, it is certainly to be regretted that they are not better posted on the principles of combustion, but it would seem to me that the less a man knows about combustion, the greater is his success as a salesman.

*Mr. Phillip McCarty*—(Smoke Inspector, Denver, Col.)—I regret to say that absence from the city at the time of the arrival of Mr. Bement's paper, made it impossible for me to forward discussion by October 17. I wish to say, however, that I had the pleasure of meeting and hearing Mr. Bement at the convention of smoke inspectors at Detroit, in June, and believe he is going into the matter more thoroughly than any one I know of, and should your Society have further discussion or papers on the smoke question, I would be pleased to receive reports of same, and possibly I may offer something in return.

*Mr. F. B. Bigelow*—(Murphy Iron Works)—We beg to acknowledge receipt of your favor of the 11th inst., enclosing advance copy of paper to be presented before your Society on Wednesday evening, October 17, by Mr. Bement, and extending an invitation to us to be present and give our experience at that time.

We are also in receipt of a communication from Mr. Bement, containing practically the same request, and we have to-day written to Mr. Bement, stating that, as his paper is exclusively a treatise on the chain grate and a recommendation of its adoption and contains the absolute statement that it is the only smokeless

apparatus made, and as the Murphy furnace is in an entirely separate and distinct class, we do not feel that we are warranted in entering into a discussion of the relative merits of these devices in public.

We will, of course, be glad to furnish your Society, or any member thereof, any data or information they may desire, regarding our device, but it is against the policy of our Company to comment on or run down any other make of apparatus at a meeting of this kind; and our understanding has been heretofore that the Western Society of Engineers has not countenanced the presentation of papers recommending the use of any one device.

Our Mr. Fitts, member of the Engineers' Society of Western Pennsylvania, will attend the meeting on the 17th and will have with him prints requested by Mr. Bement, showing the new Murphy furnace settings at the Marshall Field Retail Store and the new new Auditorium Hotel Power Plant, Chicago.

*Mr. Clinton Rogers*—(Rochester, N. Y.)—We have no smoke consuming devices here that are absolutely smokeless at all times, but we have two or three stokers that emit so little that they are considered satisfactory. As to the cheaper smoke consuming devices, we have none here that are entirely satisfactory, while they do destroy a great majority of the smoke. We have here two or three manufacturers who have a lot of waste wood to burn and while they burn that with the stokers that work satisfactory when using coal only, they do make a good deal of smoke when burning wood and coal together. There must be many such plants in the United States. Would it not be well to know of some devise that would do this?

*Mr. Frank H. Pond*—(The American Stoker Co.)—The writer has had a very extended experience, with stokers, and agrees with Mr. Bement, in his conclusions, as to how a smokeless furnace should be constructed. The American Stoker Co. are now prepared to furnish a stoker, that will meet all the conditions as outlined by Mr. Bement.

*Mr. G. S. Bergendahl*—(M. W. S. E., Koken Iron Works, St. Louis)—This subject is particularly interesting to us in St. Louis at Koken Iron Works as we have been experimenting quite extensively in the prevention of smoke. Our Mr. H. H. Hughes has invented and obtained a patent for a smoke preventer, which from the writer's personal knowledge, is as perfect as any which have come to his notice. In fact it seems to be superior to anything on the market. This device was installed, exhibited and tested at the Louisiana Purchase Exposition at St. Louis, and was awarded a Gold Medal. The devices on exhibition were later sold to the United States Government and have been used on a large per cent. of their official coal tests at the Fuel Testing Plant, St. Louis. (See report by Geological Survey, on operation of Coal Testing Plant, 1904.) This device has also been in-

stalled at numerous places by St. Louis manufacturing firms, and has proven satisfactory in all respects.

*Mr. H. L. Van Zile*—(Franklin Boiler Works Co.)—I am unable to present anything which would be of special interest in this discussion, but one matter however, which might be a matter of fruitful discussion, was brought out in a conversation which I had with a very eminent engineer here in New York, a week or so ago. He told me that he blamed the manufacturers of boilers, stokers, etc., because they had not paid enough attention to educating the users of the same so as to get the best results, and that all of the improvements in operation had come from the mechanical and consulting engineers, rather than from the instructions of the manufacturers of the apparatus, and that therefore, in a large power plant which he was desinging, he was going to employ an expert chemist and physicist, to have charge of the boiler room. He claimed that the furnace was simply a chemical appartus which should be under competent supervision of a scientist, to see that the chemical process was properly completed and that his most constant attendance was necessary, he being equipped with apparatus to analyse the coal and obtains its thermal value, also pyrometers and continuous $CO_2$ recorders. He would, therefore, be obtaining continuously the very best test conditions in manipulating the fires which, together with test conditions on the boilers, owing to the fact that they were continuously kept clean and the settings kept in perfect shape; it would be expected that a continuous economy, as shown by the best test on any type of apparatus, would be obtained all the year around, the saving in coal being a great deal more than paying for the salary of the expert.

If this is necessary and possible in large boiler installations, is it not a fact that an approach to it in smaller installations would be equally beneficial, and that given a good boiler and any one of a number of so-called smoke preventers or stokers, it would be found that smoke would be practically eliminated and better economy obtained by the intelligent use of the apparatus. The sweeping condemnation of smoke preventing devices is not always fair, because when the manufacturers operate the same and demonstrate that they are effective, they are able to sell them and get their payments. Afterwards the owners find that they are not working well or doing what they expected, and therefore, they say they are no good. Personally, the writer believes that there is no form of increased expenditure on a plant that will return as big a percentage as the employment at better salaries of intelligent men to run the apparatus in the boiler room.

*Mr. J. L. White*—(of the J. L. White Furnace Co.)—We will offer a few suggestions that we have found important. We have never seen a furnace that will burn smokeless in an internally fired boiler or under any boiler so constructed that the volatile

gases are allowed to impinge against a cooling surface before proper combustion has been completed. Hand fired furnaces and mechanical stokers constructed with fire brick arches, which insures a high temperature with a proper mixture of air heated and intermingled with the gases of combustion, will insure smokeless combustion. Take for example chain grates. It is a well known fact that without overhead arches to insure temperature from the heated brick, a chain grate fire would soon die out. But even with overhead arches or extension furnaces so built that the gases flow immediately against tubes with their low temperature will allow the volatile gases to pass off unconsumed in form of smoke. Many stokers as well as hand fired furnaces will be nearly smokeless one day and the next day, with conditions changed, the same chimney will emit large volumes of dense smoke, while many furnaces are smokeless under favorable conditions. We make the statement that the same settings will throw large quantities of dense smoke if the load is increased or the wind changes so as to affect the draft. We are of the opinion that with forced draft properly applied, *i. e.*, thoroughly distributed with either mechanical stokers or hand fired grates, placed in an extension furnace, is the nearest solution to the smoke problem, because forced draft can be regulated to suit the conditions, and should be so regulated that only the necessary quantity of oxygen is supplied to insure perfect combustion. Therefore the whole solution resolves itself into air and heat. With natural draft, it is impossible for the air traveling at the same speed as the volatile gases, to overtake and intermingle, so as to ignite the latter before this mixture has come in contact with cooling surfaces. While with forced draft the volatile gases may be held in suspension, as it were, until the oxygen is intermingled and combustion is insured.

*Mr. E. H. Hovey*—(Hydro-Carbon Furnace Co.)—While marked progress is being made in all other departments of engineering, the furnace end from which power emanates, as also the smoke, has been sorely neglected. Boilers and furnaces of recent construction, exhibit violation of chemical truths to a lamentable degree, showing but little progress in effecting further combustion either on land or sea, since the days of Watt. This we have verified many times over by chemical analysis of the flue gases.

We never trouble ourselves in the average steam plant whether we have effected the proper chemical mixture in our furnaces or not. This can only be corrected by a sound and more scientific knowledge of the subject of perfect combustion, which can only be attained through the aid of chemistry.

The combustion of coal is twofold in its nature, first, the gaseous part has to evolve before combustion can take place with the fixed part, the fixed part being compelled to take its turn;

the gaseous part is in proportion one-fourth of the given quantity of coal and as this one-fourth is evolved quickly and escapes readily under pressure of draft, it is necessary to combine the oxygen therewith, while it is at a temperature of ignition and during its evolution in the general furnace; otherwise a great loss of heat units is incurred, an incidental loss in steam power and a gain for the coal seller. It makes no difference how the oxygen for combustion is provided, so long as it gets there and makes the proper mixture, but the *mixture* is all-important. This seems to be lost sight or by many of the manufacturers of patented furnaces, the gases being allowed to pass off without being driven into mixture. The difficulty is how best to get in the oxygen so as to burn the coal economically, to have the fire under good control, and to keep the steam pressure at the desired point. And it is a difficulty that has been troubling the world since we have had steam boiler plants in use and any effort to overcome which, should meet the encouragement of every steam user. The proportions which the gaseous part of the coal bears to that which is fixed, is one-fourth, and you cannot, with advantage, supply the oxygen therefor by taking in air by the ash-pit doors. Therefore, it has been found necessary to take air in over the fire, but just how much and in what velocity can only be determined by experiment.

We regard the design of our steel door apparatus that takes the place of the ordinary charging door as the limit of perfection of feed doors, as it takes the air in, in narrow, thin sheets and is susceptible of adjustment with our retort system to any grade of bituminous or gas coals, sawdust, shavings, or factory refuse of any kind, so as to burn them without violation of the laws of any city or state and the suppression of the smoke nuisance, providing the furnaces are run according to our simple printed directions.

*Mr. A. Bement*—It was my wish to secure as valuable discussion on this subject as possible, and as certain requirements for stoker action necessary for a strictly smokeless apparatus were defined in the paper, the Society extended an invitation to all makers of boilers and furnaces to participate. To what extent they responded is apparent by the foregoing. In such cases as it appears necessary, I have made reply to the different speakers and writers, identifying my remarks by the name of the contributors. These remarks follow later, but it is first desirable to consider somewhat in deail, the conditions governing smokeless combustion.

Some years since, Prof. Wm. Kent defined requirements as follows, which also appear in his discussion of this paper:

"1. That the gases be distilled from the coal *slowly*.

"2. That the gases when distilled are brought into intimate contact with sufficient supply of very hot air.

"3. That they are burned in a hot fire brick chamber.

"4. That while burning they are not allowed to come in contact

with comparatively cool surfaces, such as the shell or tubes of a steam boiler; this means that the gases shall have sufficient space and time in which to burn before they are allowed to come in contact with the boiler surfaces."

At the time, the above was the most complete and concise statement of the requirements covering smokeless combustion of bituminous coal. It is now. however, possible to define them in a more exact manner, therefore the four different items may be considered as follows:

1. Instead of the gases being distilled slowly, the distillation should be *uniformly* effected. The expression "slowly" is a relative, not an exact one, but for distillation to proceed slowly, would require that the fuel be fed at a reduced rate, and this would have a corresponding effect on steam production.

The reason why the uniform distillation of the gases is essential in securing a smokeless result is, that if a relatively large quantity of coal is added at a time, there will be a correspondingly large evolution of gas which will be in a huge mass, and for reasons described later, may, and often does escape without burning.

2. This demands that a sufficient supply of air be available and that such air be very hot.

Regarding the first feature, there is practically always a sufficient amount of air present, and the temperature necessary for combustion is not so high as sometimes supposed. The inference in the second feature is, that the air supply might be from an independent source, such as by means of special openings into the furnace, or by means of air or steam jets. Such supplementary supply, however, is not required as far as quantity is concerned, because a sufficient amount naturally enters through the grates and fuel bed.

3. Under this requirement it is specified that the gases be burned in a hot fire brick chamber. This is really the most important of the four, the significance of which is, that they be given an opportunity to burn, or to be more exact, that an opportunity be afforded for the combustion process which is begun at the fire to continue uninterruptedly. The gas masses, or flames, entering the chamber from the fuel bed have a sufficient quantity of air entering with them, but in individual strata or masses; and owing to the fact that the gas and the air are in these individual masses or strata, there can be no combustion while such condition exists because the oxygen of the air cannot come in contact with the individual atoms of carbon in the interior of the masses of gas. If this separated condition between air and gas continue until they have reached the cool surface of the boiler, the temperature will be reduced to a point where chemical union cannot take place, even if the air and gas are then thoroughly mixed together, therefore the office of the hot fire brick chamber is to retard and delay the cooling effect from the boiler until the gas and air masses have

become mixed together or the gas masses or flames have been consumed. Such fire brick chambers are of two kinds: one consisting simply of a large open space built of refractory material in which the flames and air enter at one end and the gases of combustion discharge at the other. Or the same form of chamber in which are located fire brick obstructions with which the gases and air must necessarily come in contact and in so doing are deflected in their travel against each other, stirred up and caused to mix together; thus the office of the fire brick chamber which may be designated as a furnace to distinguish it from the grate, is to cause the gases to become mixed together naturally, which they would do in a plain chamber, providing too much mixing is not required; or in other words, if they enter in a state with the mixture already nearly effected, as would be the case with a properly operated stoker. But with a hand-fired grate, or an irregularly operating stoker, the masses of gas may flow entirely through the plain furnace chamber before mixture is naturally effected; therefore, when the evolution of the gas is not at a uniform rate, the furnace chamber containing therein mixing walls and baffles is necessary; even with the most elaborate mixing chamber of this character, combustion will not be complete unless the evolution of the gas approaches uniformity, sufficiently so as not to overtax the mixing capacity of the chamber.

Great stress is usually laid upon the necessity for high temperature in such furnace chambers. Inasmuch, however, as the union between carbon and oxygen will occur at what might, in this connection, be called low temperature, it is really not essential that the temperature be what would properly be termed high. Inasmuch, however, as the boiler can take no heat from the gases while in the furnace chamber, the temperature therein is sufficiently high to make the walls very hot, although this temperature in the brick work is not especially essential. For example, if instead of fire brick, a material could be used which would absorb no heat, it would not become hot, but would, however, prevent the burning gases from coming in contact with the boiler, and therefore would perform the same office as does the fire brick which necessarily becomes heated. This is further illustrated by the fact that if a boiler be set a sufficient distance above the fire grate, the gases would all be burned before they reach it, although the process would take place immediately under the exposed boiler.

4. The fourth item of Prof. Kent's requirement is really covered by the third one, but too much stress cannot be laid upon the fact that it is absolutely necessary to have the mixture of the air and the gases effected before the heating surface of the boiler is reached; or in other words, that the flames shall not extend to the boiler. This is something that should be especially emphasized, because it is a very common belief that it is the flames more particularly which convey the heat, and that they are evidence of fire.

This is not true, because a flame gets its luminosity from the solid particles of free carbon which have become heated to redness, and inasmuch as they are free, it follows that they have not been burned, and therefore have not given off heat; the heat required to effect their luminosity having come from other sources; as soon as oxidation of such particles occurs, carbon dioxide is formed, which is a colorless gas and not luminous, and this combination is accompanied by the evolution of the heat which is carried to the boiler surface from the furnace chamber by the carbon dioxide, nitrogen and superheated steam, which make up the total of the gases of combustion. Therefore it is necessary to realize that a flame is not fire, but rather something which may become fire.

From the standpoint of present study, Prof. Kent's requirements may be modified to two features as follows:

1. That the evolution of the gas from the coal shall proceed uniformly.

2. That the gases which are distilled uniformly from the coal shall enter a fire brick chamber of either sufficient length to allow the flames to become entirely consumed naturally, or that the chamber be provided with such auxiliary mixing and baffling devices as will cause the gases to be artificially mixed together before the exit of the chamber is reached.

The efficacy of either of the above features is dependent to a very great extent, upon the comprehensiveness of the other. For example, if it is possible to have great uniformity in the supply of coal and consequent evolution of the gas, the furnace chamber may be of the simplest character; or if it is not feasible to use a furnace chamber provided with the auxiliary mixing features, such as the baffle walls, etc., then it is essential that provisions be made for maintaining uniformity in the distillation of the gases; or again, if the mixing capacity of the chamber is at its maximum, then it will be feasible to utilize a coal feeding condition which is less uniform than would be necessary with the plain chamber.

The matter may also be illustrated from the standpoint of the flames, and a distinction may be made between large and small flames. For example, gas will be distilled from a piece of coal, and the solid carbon therein will become heated and luminous, or in other words, a flame will proceed from the piece of coal, and this flame can burn only on the outside, because the air flowing up around it can only come in contact with the exterior of the flame; therefore, a large piece of coal will make a large flame, and a small one a small flame. Or, should there be an accumulation of clinker on the grate, the air supply to the fuel above is largely excluded and for this reason massive flames will be produced by fresh fuel lying above the clinker; or, if a large quantity of fuel is placed on the fire at one time, there will be a corresponding evolution of gas and consequent massive flames produced; or again, an improperly operated stoker of the non-positive feeding type will produce an

irregularity in the fuel supply similar to that with a hand fire and massive flames will result. Therefore it follows that small flames are sooner burned away than large and massive ones, and for this reason it is necessary to produce short flames and provide a simple combustion chamber for them to burn in, such as would be secured by a chain grate stoker and such furnace chamber as shown in Fig. 1, or else for large and massive flames, provide a furnace chamber in which are located mixing devices such as Kent's wing walls. Figs. 15 and 16, or the piers in the design mentioned by Mr. Kuss, Figs. 2 and 3, or that mentioned by Mr. Bean, Figs. 17 to 20. Thus we may have two distinct types of furnace, one a plain chamber, the other a chamber with auxiliary mixing devices.

This view of smokeless combustion from the standpoint of the flames, I think is the one which has been most instrumental in affording a clear conception of furnace performance. It is very easy with a chain grate stoker and the plain furnace, to obtain positively smokeless combustion, although strictly speaking, its mixing capacity is zero, because the flames flow directly through it and burn away naturally, while the chamber with the special mixing devices causes the masses of air and gas to be suddenly brought together and mixed one with the other. The capacity of this type of furnace for producing complete combustion is enormously greater than that of the plain chamber. Notwithstanding this fact, however, it is difficult to devise a mixing chamber having sufficient capacity to completely mix the gases issuing from a hand fire, unless it is manipulated with some care, although it is not at all difficult to fire them so that there will be no smoke.

Kent's wing wall furnace is probably the oldest recognized example of a design worked out for the particular purpose of accomplishing the result here mentioned. Its capacity, however, is limited, or in other words, it will burn only moderately long flames. which means, that with a hand-fired apparatus, a smokeless result will be secured, more particularly by careful firing than by the apparatus itself. The Woolley furnace is an example of a furnace chamber having a maximum mixing capacity, because the gases are compelled to flow through and pass various obstructions, in such manner as to stir them together to an extent not secured by any other apparatus with which I am familiar, unless it may be that shown in Figs. 2 and 3. The more or less complicated brick work in this general type of mixing chamber, while being very effective as far as promoting combustion is concerned, interposes a resistance to the draft. On the other hand, however, the high temperature of the chamber causes the coal to burn very much faster than it would otherwise do, therefore, while the complicated passages may reduce the draft, the higher temperature causing more coal to be burned, will ultimately result in the capacity being increased rather than diminished in all cases where the design is properly worked out. The brick work, however, unless very

carefully constructed of very good material, will suffer from the action of the high temperature and corrosion of the gases, so that it is always absolutely necessary to employ the very best quality of material and workmanship in its erection.

In all furnaces, whether of the plain or mixing chamber types, there is a considerable quantity of ash carried by the draft into the chamber, and there fused into a mass. When the boiler is shut down and the combustion chamber cleaned, the solidified cinder is easily broken up in the simple chambers, but its removal from the mixing chamber is more difficult. For example, in Figs. 2 and 3, there would be a tendency for the molten cinder to gather around the bottom of the piers, and its removal might disturb them. Mr. Kuss suggests that those piers be laid in fire clay, but it is not altogether certain but what in many cases it may be more advisable to lay them up with loose brick work, so that if disturbed they may be easily replaced and at small cost.

From the above it appears that we have the choice of two distinct systems for securing smokeless results. One, that of the positive feeding stoker provided with a simple combustion chamber, or an irregularly working stoker, or hand fire, provided with the mixing chamber. With the latter, success will depend in a considerable measure in every case, upon careful firing or manipulation of the stokers, because as far as experience to date has demonstrated, none of the mixing chambers have sufficient capacity to burn the massive flames that are often produced, while with the positive feeding stoker and simple chamber, the problem is an easy one, not only as far as the process itself is concerned, but the apparatus is very durable. For example, the roof of the chamber is suspended on the bottom row of tubes of the boiler, and for this reason the tiles are somewhat cooled and cannot be damaged by the heat as can brick work entirely exposed to the full intensity of the heat, when so situated that it must necessarily accumulate the full temperature.

Mr. Elliott has one of the model chimneys in the city, and its condition is due to the careful manipulation of the Murphy stoker he employs. If, however, one will go to the Chicago Stock Yards, they will find that one of the chimneys there, a photographic view of which is shown by Fig. 21, serves water tube boilers of the same make, equipped with exactly the same stoker as his, and that it continuously produces very black and heavy smoke; this is also true of two other important chimneys in the Yards, although a different type of boiler is there used with the Murphy stoker. This emphasizes a point which I have endeavered to make, that there is certain apparatus which will be smokeless when carefully operated, but if carelessly fired, will produce much smoke. This is true of the Murphy furnace, and we might just as well realize that careful operation is the main essential for its success. And if one wishes to study this feature of the matter, they may readily ob-

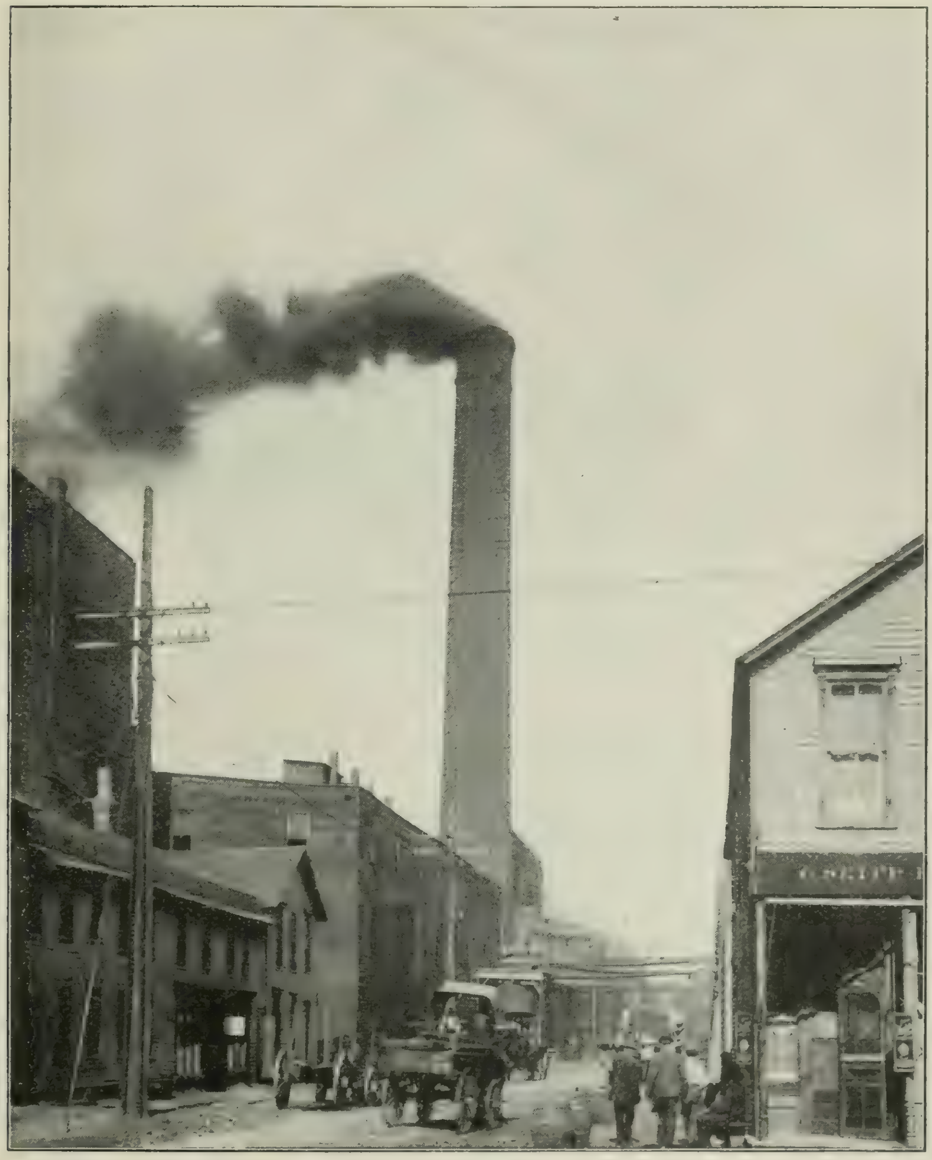


FIG. 21. USUAL APPEARANCE OF CHIMNEY SERVING MURPHY STOKERS LOCATED UNDER BABCOCK & WILCOX BOILERS.

serve Mr. Elliott's chimney on Fullerton Ave., a short distance west of the Northwestern Elevated Ry. structure, and also see the others at the Stock Yards from the Halsted St. cars, or to better advantage from Ashland Ave.

One of the prevailing excuses for smoky chimneys with that character of apparatus requiring careful manipulation is, that it is overloaded, and in this connection, it is interesting to note the load carried in some important electric stations as compared with that of the Northwestern Elevated Railway. Some time ago I made figures on a large number of stations, and found that the Northwestern Elevated were actually generating a kilowatt at the

peak of the load with 0.052 sq. ft. of grate surface. The next smallest unit of grate surface per kilowatt was that of the New York Edison Co., which was 0.071 sq. ft. this latter station being equipped with forced draft in addition to high chimneys. And this figure for grate surface ran up to over 0.150 sq. ft. per kw. for other stations in the country, from which it appears, that notwithstanding the fact that Mr. Elliott's chimney is almost smokeless, his furnaces are worked at a much higher rate than many people suppose possible.

Mr. Goddard calls attention to the difficulty of obtaining and keeping a good man for the fire room, and in this connection I wish to say that we expect too much of this class of labor. It is often the case that an engineer, manager or proprietor seeks a degree of intelligence in men of this class greater than they possess. It is unreasonable to expect that educated young men will go in the fire room, unless the character of the apparatus is such as to reduce the labor requirements to the minimum. For this reason it is absolutely necessary to develop and perfect types of mechanically operated apparatus that intelligent and clean men will be willing to run.

Mr. Saxe was fortunate in making the experiments he did to determine whether the circulation of the boiler had been "reversd" or not. This bugaboo of reversed circulation has been one set up to scare many well intending people. Just where it originated it is difficult to say, but no doubt in the camp of the rival boiler men. One of the stories circulated regarding "reverse circulation" concerned a plant in this city, equipped with Heine boilers, which when serving large engines, discharged a considerable quantity of water with the steam and caused trouble with these engines. The boilers, served by chain grate stokers, were equipped with tile roof furnaces, and the story was, that the presence of these roofs which had been added to the boilers after their original installations, caused the water and steam to flow up the rear leg to the drum instead of the front one, and produce wet steam.

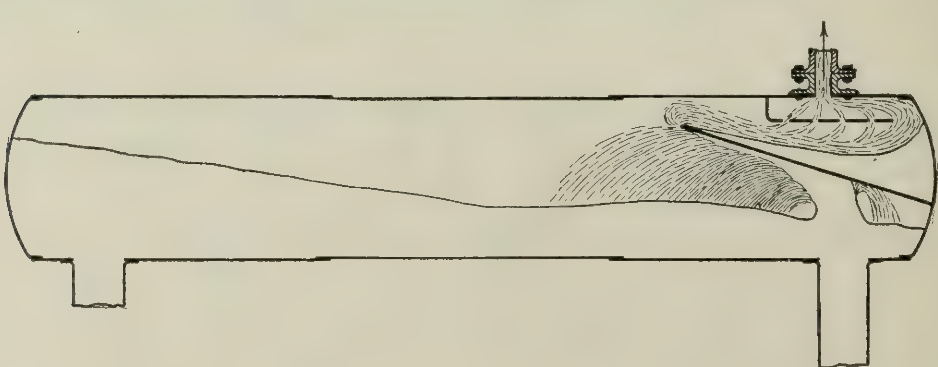


FIG. 22. STEAM DRUM OF WATER TUBE BOILER SHOWING WATER DEFLECTING BAFFLE AND ITS DISPOSITION TO MAKE WET STEAM.

It is unnecessary here to go into details, because the case has been fully described elsewhere.* The action of these boilers in this respect, both before and after the tile roof was applied, is shown in Fig. 22. Had the circulation been "reversed," we have presented in Fig. 23 the action which would have taken place.

FIG. 23. WATER TUBE BOILER DRUM SHOWN IN FIG. 22 AS THE ACTION WOULD BE IF THE CIRCULATION HAD BEEN "REVERSED."

showing that if the boiler had only worked backwards, instead of making wet steam, it would have made very much drier steam than with normal circulation.

Mr. Edwin Fitts of the Murphy Iron Works, does not want to discuss the feature of the grate or stoker, because it "would bring in matters foreign to the subject of the evening, and would necessarily be at issue with statements in Mr. Bement's paper."

I do not see how it would be foreign to the subject of the evening, because if anything, the object was to ascertain facts concerning the behavior of stokers or any other feature of the allied apparatus, and if he had any occasion to take issue with statements which I made, it certainly was his duty to present them and to expose any errors or mistakes of mine, and it is most desirable that he do so if possible.

Mr. Joseph Harrington—It appears to have been assumed when chain grates were first used in this country, that because they were stokers, they would be smokeless under all conditions. Upon the discovery that they were not always so, there has been more or less experiment with various forms and lengths of ignition arches. but with the regular Babcock & Wilcox or similar boiler design, it is impossible to get an arch of sufficeint length. What is known as a "flat arch," however, is really more effective under such boilers than the greatest length of sloping arch usually obtainable, for the reason that it holds the gases down closer to the fire, interferes with their natural flow and causes them in their struggle to escape to be mixed together with the air to a greater extent

* Transactions of the American Society of Mechanical Engineers, Vol. 26, Page 312.

than when there is a high flaring arch which affords an unobstructed flow. This flat arch scheme, however, while very much better than nothing, is only a partial remedy. Personally, I am very much prejudiced against any plans which attempt to effect entire combustion by the aid of the ignition arch, because they can be successful to only a limited extent, but sufficiently so in some cases, as to prevent people doing the work in a proper manner.

Such form of arch shown by Mr. Harrington in Fig. 12 is only partially successful. They are better, of course, than short arches, but they are not smokeless, as one may observe in St. Louis, by noting the eight shorter chimneys which emerge from the boiler house of the electric station of the Union Electric Light & Power Co. These are the chimneys which serve boilers equipped with the arch and stoker shown in Fig. 12.

We look at matters from different standpoints. The stoker maker may be satisfied when he has done the best he knows how and call it good enough, and gets into the habit of thinking of it as being the best that can be accomplished; so with schemes like these, which are, of course, very much better than would be obtained with an ordinary hand fire, but fail entirely to meet modern requirements.

Mr. Harrington states that his company has a number of installations in Chicago, and the greater portion of them are entirely smokeless or nearly so. It would have been more to the point had he given the names of the owners and locations of some of these, so they could be looked up. I will mention, however, two plants containing Green travelling grates in the Stock Yards; one is the Hammond plant of the National Packing Co., the other, Nelson Morris & Co. One of these plants is equipped with Stirling boilers having the usual supplementary Stirling arch, which is a necessary accompaniment of this type of boiler. This plant makes almost no smoke at all. The other has Babcock & Wilcox type of boilers, and its chimney is one of the most persistent and worst smokers in the Yards.

The Stirling boiler which Mr. Harrington mentions, is the one referred to by me as the only example of an apparatus approaching a smoke proof character, supplied by one manufacturer, the inference being, that if the Stirling Consolidated Boiler Co. would furnish one of its Stirling boilers and Cahall chain grates to a purchaser, it would enable him to obtain this single example of apparatus approaching a smoke proof character obtainable as a single purchase from one maker.

Mr. O. U. Bean has an apparatus, wherein the mixing feature is developed to almost the maximum. If its brick construction will stand the high temperature, and it does not slag up to a harmful extent, it will prove a good device. It is not probable, however, that it is so nearly smoke proof as he considers, but it should be at least a very easy one to fire smokelessly. He certainly has

defined strict requirements for a smokeless apparatus of this kind, and he has assumed a considerable burden in offering to "make good" on all of these points.

Prof. Wm. Kent: It is well that Prof. Kent calls attention to what he designates as the stratification of the gases. This is a feature upon which I have dwelt to considerable extent in connection with the behavior of furnaces with plain and mixing chambers. In reference to his example of smoke flowing in a stratified condition for several miles in the air, attention should be called to the fact that no such thing could occur with highly heated gases, because they would disappear owing to burning away on the outside; this cannot occur with smoke, because it is not hot.

Regarding his criticism of the plain chamber shown in Fig. 1 having no means for mixing the air and gas together, it should be stated that with such chamber when served with a chain grate stoker, its length is sufficient to insure that the flames will be naturally burned before the exit is reached. As mentioned elsewhere, with other types of stokers or methods of feed of fuel, it may be very difficult to obtain sufficient mixing capacity to entirely accomplish the result.

Mr. Woodward appears to consider that the apparatus shown in Fig. 1 is only suited to cases where the load never varies, and mentions such service as rolling mill, electric light, street railways, etc., as a class of service that could not be rendered by such apparatus; in reply I would say that very nearly the entire volume of electric current generated in Chicago, is by plants equipped with chain grates, and there is no trouble. In fact,, chain grate stokers are successfully handling all kinds of intermittent loads.

Mr. Woodward should realize that the statement regarding uniformity of feed is one referring to intervals of short duration, or in other words, while the fire is in action; for example, with a hand fire, the man may supply coal every five to fifteen minutes, but the stoker on the other hand, would work uninterruptedly even on an electric peak, for at least an hour, during which time the feed of the coal would be continuous. In some intermittent service, the steam might be blowing from a safety valve a portion of the time, while during another portion, steam pressure might be falling, yet the loss of steam from the safety valve would be no greater than that due to chimney losses from excess of air, caused by short fires, during reduced load.

Mr. Horton has presented a very interesting and important feature of the matter in demanding some standard by which to judge the quantity of smoke. The old idea was to assume a maximum which was called probably, 100 per cent. or dense black, and then to guess that a lesser quantity might be, for example, 50 to 25 per cent., which is very unsatisfactory. Even the more refined scheme of Ringelmann's smoke scale is entirely inadequate.

Personally, I think the condition which should be called zero smoke or absence of smoke, would be that which is not indicated by the photographic camera, therefore if it cannot be discovered by the photograph whether a plant is in operation or not, it may be declared smokeless. As a matter of fact, however, a photograph never shows the chimney at its worst. For example, in cases where a light haze of floating ash from the chimney may readily be observed, the camera gives no record whatever. It is, however, desirable to have a clear understanding as to what might be implied by absolute smokelessness or the action of a smoke proof apparatus, because there is no furnace apparatus whatever, using bituminous coal, which can be originally put into action without making some smoke; that is, it will smoke when the fire is first lighted, but if it is what I have designated as being smoke proof, it will cease to smoke as soon as the fire and furnace get into action.

Mr. Horton's argument is, however, that it is not only impossible for smoke to be prevented, but that it has never been done, therefore it gives me pleasure to submit herewith Fig. 24, showing a

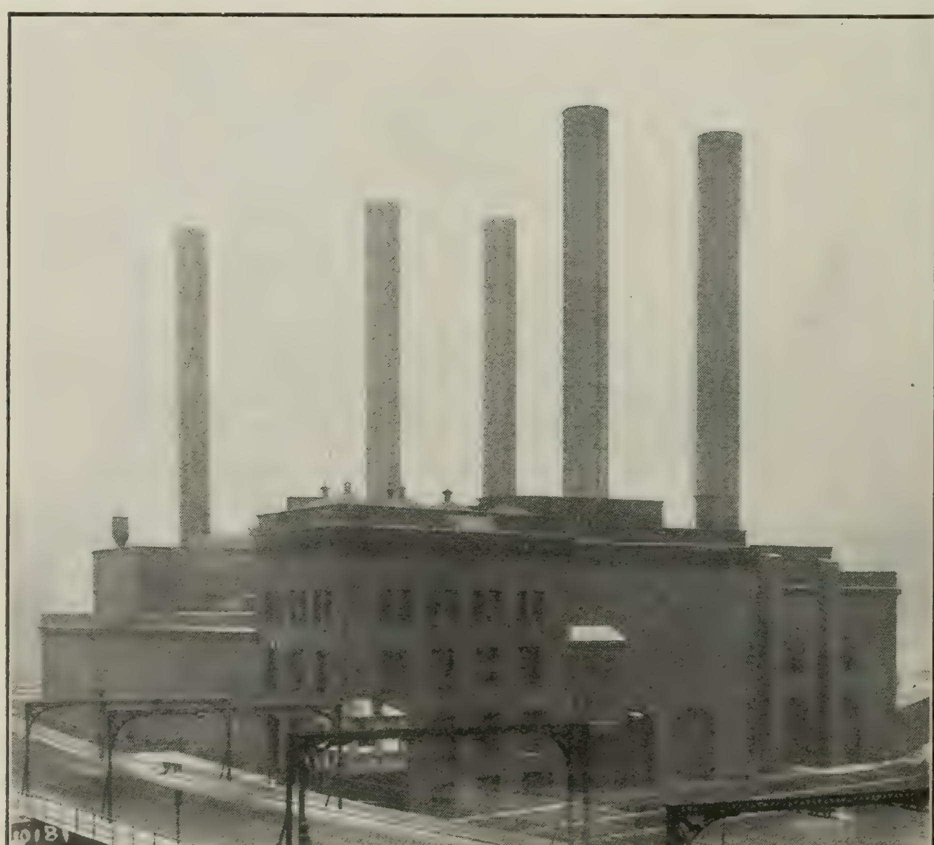


FIG. 24. HARRISON STREET STATION OF THE CHICAGO EDISON COMPANY. FOUR LARGE CHIMNEYS SHOWING ACTION OF SMOKE PROOF FURNACES EMBODYING THE PRINCIPLES ILLUSTRATED IN FIG. I.

plant which has run for over five or six years without producing sufficient smoke to make any more impression than that indicated by this photographic view. The chimneys in question are the four large ones. The smaller one to the left hand serves a different type of apparatus. This plant is located at Harrison St. and the south bank of the Chicago River, and it may be observed by any interested party as an answer to Mr. Horton's assertion.

The statement that the amount of smoke produced has increased at the same rate as coal consumption, is a serious error. I have stated publicly, that in the last twenty years, smoke in the down town district has been reduced by one-half. This may or may not be true, but at all events, we may all agree that it is not greater today than it was in 1886. In 1880, Illinois produced 6,000,000 tons of coal, and at the present time, the annual production is as high as 38,000,000 tons, which shows an increase in coal production of six times, and inasmuch as the increase is at a much greater rate in the cities than in the country, it follows that its use in Chicago is at least six times greater than it was twenty years ago. If those who wish to give this matter a little study, will take into consideration the large electric and street railway plants which were not in existence at that time, and will endeavor to imagine what the effect in the way of smoke production would be today if they were equipped with the same character of apparatus that was almost exclusively in use twenty years ago, they may be able, with a good imagination, to conclude what the effect on the atmosphere would be.

One of Prof. Kent's statements will also apply to the argument made by Mr. Horton.

Mr. Bigelow's letter is to me, one of the most valuable of all of the discussion, because it presents, I think, the attitude of very many manufacturers.

The statement is, that my paper is "exclusively a treatise on the chain grate and a recommendation for its adoption, and contains the absolute statement, that it is the only smokeless apparatus made."

If there are any errors in my statements in this paper, it was his duty to point them out clearly and prove their fallacy, because it is just as bad for the public to be misled by the assertions or statements of an engineer, as it is by those of anyone else.

The only reason why I recommend the chain grate is, that it assures a positive and uniform feed of the coal and a like removal of the ash, and that in so doing may become one feature of a smoke proof steam generating apparatus; if the Murphy furnace would do this as well I certainly would much prefer it, because it has features of advantage not possessed by the chain grate.

My remarks applying to the discussion by Mr. Elliott, I think will make my position clear. Any criticism I have made of the Murphy applies with equal or greater force to other types of sloping grate stokers.

Mr. Rogers asks for a form of furnace or stoker apparatus suited to the burning of both wood and coal.

The Murphy furnace as mentioned by Mr. Saxe is something which lends itself excellently to this combined service. The Acme stoker has also been proposed, and has sometimes been installed to burn both wood and coal. The Hawley furnace is another apparatus especially well equipped to burn wood and rubbish together with coal, although, of course, like the two above stokers, it must be carefully manipulated to be smokeless with either or both fuels.

Mr. Bergendahl's discussion is especially interesting, as it illustrates the confidence some of the manufacturers have in their apparatus.

I presume the sale made to the U. S. Geological Survey for application to the boilers in the fuel testing plant at St. Louis may be considered an excellent stroke of salesmanship, and the publication in Professional Paper, No. 48, of an illustration of this device may have been instrumental in assisting sales of it, but for its operation, I presume we may obtain some data from the remarks of Mr. Kreisinger, wherein he appears to give the fireman credit for such smoke suppression as realized, although he states that some coal made 50 per cent. more smoke than others. Therefore, there must have been a large amount of smoke made at times.

Mr. Van Zile I think introduces an interesting and important feature of this matter, in mentioning that manufacturers have been criticised for not teaching the public how to operate the apparatus they sell, and I consider it well to emphasize the fact that the responsibility of the purchaser is just as great as that of the maker, and that he is too often looking for an opportunity to throw the entire obligation on the maker. Further, I do not think the maker should be expected to run a school in connection with the manufacture of boilers or furnaces, at the same price that they get for the apparatus.

Mr. J. L. White suggests hollow grate bars and a forced draft therein as a remedy for smoke. This is one of the old ideas that like very many others, have been exploited for a considerable time, but is no more effective than any other common hand-fired grate, the result in both cases being dependent upon the manipulation or care in firing, and not through any virtue of the apparatus itself.

Mr. E. H. Hovey's discussion is decidedly of interest. Here we have an argument which would convince very many purchasers that slots in the fire door will prevent smoke, yet the country is full of such schemes as this, making just as much smoke as could have been produced if they had never been applied.

In conclusion, some attention should be given to the tiles used in the formation of furnace roofs. This scheme of furnace roof originated at the Harrison St. electric generating station of the Chicago Edison Co. some years ago, a rectangular tile being first

used to encircle the lower row of tubes of the boiler, and the success attendant upon their use caused the maker of these particular boilers to adopt the use of tiles which were quite generally applied to new boilers as built, but they were of a form shown in Fig. 25, were made in large quantities and carried in stock by the

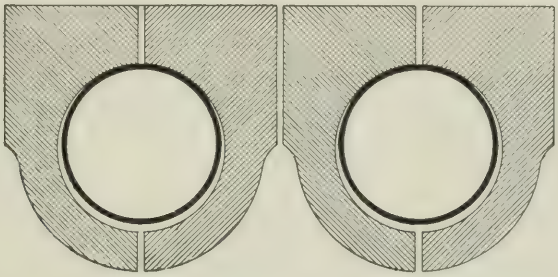


FIG. 25. HEINE "C" TILE. AN IMPROPER DESIGN SOMETIMES EMPLOYED IN THE FORMATION OF THE TILE FURNACE ROOF.

boiler company, thus a large number of them were supplied to people who desired to apply tile furnace roofs to their boilers already in service. The design of the tile, however, was faulty, inasmuch as that portion exposed to the fire was not sufficiently thick to insure necessary strength. In addition to this, the material used was not of good quality. The result was, that this form of tile failed rapidly in service, so much so as to cause people to abandon the use of the tile roofs in a good many cases. It was a design, however, which makers of refractory material preferred

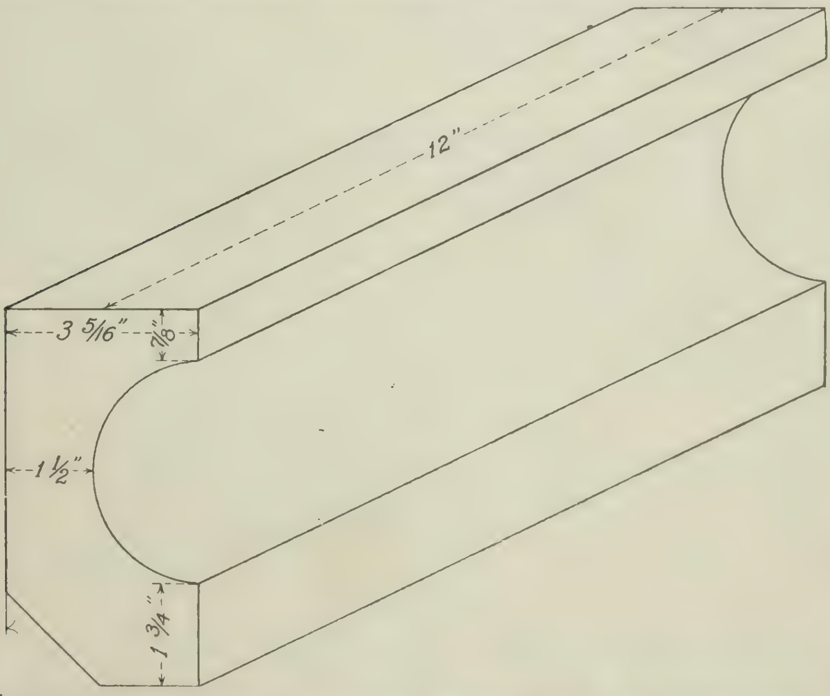



FIG. 26. ENCIRCLING TILE. STANDARD DESIGN USED IN FORMATION OF TILE FURNACE ROOF.

to use for reasons of manufacture, and it has been adhered to by them to a considerable extent. Therefore, all who wish to obtain a successful furnace roof, should decline to accept tiles of this particular design, notwithstanding that they may be made of good material.

After the failure of the above-mentioned form of tile, the design shown by Fig. 26 was made by the Chicago Edison Co., and it has proved very successful. Fig. 27 is a detail of a section of the fur-

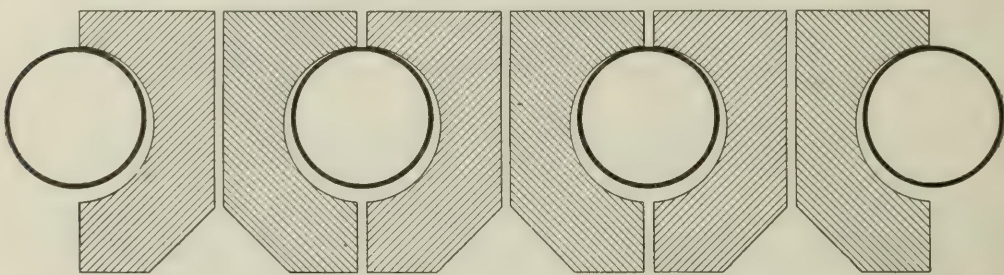


FIG. 27. DETAIL OF TILE FURNACE ROOF SHOWING TILES ILLUSTRATED BY FIG. 26 AS SUSPENDED BY THE BOILER TUBES.

nace roof formed by it. This tile has a long life when made of the best material, although the use of a more refractory material than that employed by the fire brick manufacturers would, no doubt, be profitable, and I have endeavored to have some shapes made of siloxicon, but so far have been unsuccessful, because to date, it would appear that it has not emerged from the experimental stage. Bauxite, however, promises to offer a solution in those cases where a refractory material of high resistance is required, and it is my hope that records concerning its performance will soon be available.

The Publication Committee and the author are indebted to Mr. F. S. Peabody for use of many of the illustrations in this paper which are from the Peabody Atlas now in press.

## THE TESTING OF COAL.

A. Bement, M. W. S. E.

*Presented Oct. 3, 1906.*

The purchase of coal under specification stipulating its composition, and the analysis of the fuel delivered under such specification, has now become an important feature of the coal business, and while the practice is of comparatively recent origin in this general locality, experience has demonstrated that there are certain features of specifications and analytical methods which may be corrected and improved. This applies particularly to the business transactions between the dealer who sells the coal and the purchaser who burns it. Another phase of the problem concerns the work being done at the coal testing plant of the United States Geological Survey at St. Louis, the Illinois Geological Survey and the Engineering Experiment Station of the University of Illinois. The work of these institutions may be considered as that of research, to distinguish it from the inspection service.

It is the principal object of this paper to emphasize the necessity for improving the practice governing specifications and inspection, and also to suggest certain lines along which the research work should proceed, and it is fuel coal from the Eastern Interior coal basin that is more particularly considered.

The improvements and corrections which concern terms of specifications, and the inspection service, require that determinations of the following be abandoned:—

MOISTURE,
VOLATILE MATTER,
FIXED CARBON,
SULPHUR,
EVAPORATIVE POWER OF THE COAL.

Every essential requirement of the purchaser may be fulfilled by confining specifications and tests to the three following characteristics; in fact, these three features alone will insure greater protection to the purchaser than obtainable under present general practice:

PERCENT OF ASH IN THE DRY COAL,
SIZE OF THE COAL,
HEATING POWER OF THE PURE COAL.

The latter, according to prevailing practice, would preferably, of course, be expressed in British thermal units.

The reasons for the above recommendations are given under the following captions:

### MOISTURE.

Moisture is a great and uncertain variable. It not only differs in various coal seams as the coal lies in the ground, but is af-

fected in fuel as received in shipment, by conditions of weather, temperature and time the coal may be in transit. It is approximately correct, however, to say that each coal seam has a characteristic moisture content of its own, which is uniform over at least very considerable areas, but the after influences above mentioned changes it, so that there is no assurance of what it may be except under specially defined conditions.

Therefore, the producer or coal dealer can exercise no control over moisture, and as the prime object of fuel inspection service is to insure that the customer is served to the best ability of the dealer, specifications and tests of moisture in coal delivered can offer no protection to the purchaser. As before mentioned moisture varies in different coal seams; for this reason it might appear that its determination would indicate the seam from which the coal came. This is not true, however, for reasons above mentioned. If tests are expected to identify the seam which produced the coal, other means must necessarily be employed.

However, in coal inspection service, moisture has been found to be very high in cases where delivery is by wagon, which, owing to lack of sufficient explanation of phenomena at the time, may have led to the opinion that the dealer wetted the coal for the purpose of increasing its weight at the time of loading. If this is the practice, it necessarily complicates the problem, but the writer has had cause to visit every coal yard in Chicago, and never observed any wetting of coal or any appliances for such purpose. It would be a difficult and expensive matter to wet fuel as loaded, and require water pipes located along team tracks, which in some cases extend for several hundred feet, and with the finer sizes of coal it would necessitate a man stationed at each wagon to supply water as fast as the coal was loaded, otherwise it would be impossible to add any great amount, because simply flooding the top of a wagon load of screenings, for example, would only insure the upper surface being wetted as the water would not penetrate the mass. A further study of this matter has made it appear to the author, that this high moisture in wagon-delivered coal, is due to the practice of wetting coal while it is being unloaded, very often done for the purpose of allaying dust, and to the water which is commonly added in the fire room for various reasons, both prior to the time of sampling.

This matter of moisture also complicates the problem as far as the inspection service is concerned, because it is impracticable for the inspecting company to have its sampler present when a wagon load of coal arrives, as it would entail an expense which the service could not bear. Also, sampling attempted at the time of unloading could not be properly performed, as the sampler would be unable to gather from a wagon at the sidewalk and prepare a sample as it should be done. Thus it appears, that the determination of moisture, even in wagon-delivered coal, serves no useful purpose.

With fuel received in cars, there could, of course, be no opportunity for adding water.

VOLATILE MATTER.

No fuel coal of this locality is purchased for the purpose of making gas or for use in byproduct recovery plants, therefore tests for this constituent are unnecessary, unless there be a great difference in the coal. *"Volatile matter"* is not very well understood. The best conclusion is that coal is a complicated hydrocarbon which breaks down in distillation into various fractions, depending upon temperature and duration of heating period, and that the difference in coal of this basin is not greater than that due to the varying effect produced by the volatilization test itself; or, in other words, the variation may be caused by the test rather than by the composition of the coal. Thus the volatile matter test is not sufficiently accurate to be of service in this case. It is, of course, true, that it would distinguish between bituminous, semi-bituminous and anthracite coal, but one may do this merely by inspection without any test whatever.

All coal of this basin is high in "volatile matter"; all will make smoke if burned in sufficiently bad furnaces, and all will make smokeless combustion and good efficiency in good furnaces.

FIXED CARBON.

In coal analysis the disposition is to follow precedent. Coal mining became an important industry in the East long before it did in this locality. Much coal in the Appalachian basin is suited to the manufacture of a high grade of coke, and the amount of residue, or, in other words, the coke obtained under the conditions of the process, is a matter of first importance. This has had the effect of emphasizing the importance of "fixed carbon", so that it has been looked upon in many quarters as of more moment than any other characteristic of coal, and these ideas, extending to our locality, have to a considerable extent influenced opinion regarding fuel. The same remarks regarding the uncertainty of the determination of volatile matter apply to that of fixed carbon, because the test for the former is the one giving data for the latter. If coke was made from coal of this locality, it would be possible under certain conditions, to make a useful application of the test for fixed carbon; inasmuch, however, as it is not the case, this constituent is only a troublesome and misleading feature of analysis.

SULPHUR.

Sulphur has been in a measure treated in the past the same as that of fixed carbon. In metallurgical work it is of extreme importance, and in this connection has received more attention than with fuel coal. This has given a prominence to the sulphur determination which it would not otherwise possess, and upon the as-

sumption that sulphur is in the form of pyrites or very largely so, the conclusion has been accepted that the amount of sulphur is an indication of the tendency of the ash in the coal to clinker. This is true, however, to only a slight extent; in fact, may not even be considered as a working hypothesis in this coal basin, because some of the seams which are the highest in sulphur produce the least clinkering, therefore conclusions regarding the behavior of the ash in this respect, are not justified by the amount of sulphur in the coal.

### EVAPORATIVE POWER.

This is something which should never, under any circumstances, become a feature of specifications or guarantees, for several very important reasons. In general, too many variable factors enter into the problem. For example, boilers differ, some being more efficient than others, absorbing greater or less amounts of heat from the coal for reasons due to their individual superiority or inferiority. Then furnaces differ greatly; in some cases all of the volatile matter may be burned; in others, a large portion be wasted. Again, fire grates differ in like measure, causing varying losses of fuel which falls into the ash pits, and the combination of grate and furnace has an important influence on the excess of air which necessarily enters, and for this latter reason, also, the useful result obtained from the coal is affected to a marked extent. The above refers to the characteristics of the apparatus itself; but at this point another and most serious variable must be considered, that of the personal equation of the fireman or furnace operator; therefore it is apparent that in such a test, one may be unable to discover whether the result is due to the fuel, the peculiarities of the apparatus or its manipulation. In the case of a coal purchaser who does not realize these facts, the result is always attributed to the object in view, which is, in such instance, to determine the value of the coal. If he had wished to discover whether he employed a good fireman or not, the experiment would have been precisely the same, and he would have then considered the result due to manipulation. It is not only the above features which have an important influence, but the character of the load on the plant is a matter of great moment. In a works where boilers run steadily 24 hours, the result secured, everything being equal, will be much better than in one where the work is necessarily interrupted by stoppages at noon time, shutting down at night, or with peaks of load as in electric railway service. Any one of the foregoing causes may exercise a greater influence on the evaporative result secured than that due to variation in fuel.

It is not intended in the above to imply that coal burning experiments are not useful, because there are some things which may be settled as affecting certain plants; for example, fuel high in ash generally costs less per ton than that containing less ash, and

it might be a question which would be the most economical to use; or, the matter of the most desirable size of fuel may be in question. These two are the only features which can be settled by burning coal under a boiler, and they should not be made part of a specification or guarantee, but used entirely for the guidance of the fuel user in selecting the best grade.

The behavior of coal under boilers is a problem very little understood, because it is the result of many variable influences, and for this reason it is often felt that the calorimetric test is unreliable, which however, is not true, because the calorimeter does its work very accurately as far as the coal itself is concerned, its efficient utilization in service is influenced only by the amount and fusibility of the ash associated with it and the size of the pieces of the fuel. This matter has been extensively treated elsewhere.*

It is well in this connection to direct attention to the fact that there is a feeling more or less prevalent, that coal from different localities or seams, may possess some undefinable peculiarity in its chemical combination, which causes it to behave differently under a boiler than it would in a calorimeter. Such conclusion is untenable, because the process is identical in each case, that of combination of oxygen with the carbon, hydrogen and sulphur of the coal, and this combination cannot be any different under the boiler than in the calorimeter, unless certain influences due to the peculiarity of the boiler apparatus and its manipulation assert themselves, and it is the disposition as far as the coal is concerned, to blame it for effects which are due to causes other than its chemical composition. It is well in this connection, to call attention to the fact that the heating power of the coal proper, or, in other words, the pure coal in Illinois, only ranges from 14,000 as a minimum, to 14,750 British thermal units as a maximum, and that about 80 percent of the fuel produced ranges from 14,000 and 14,500 British thermal units per pound. Thus the enormous variation found in service under boilers as far as the amount of water evaporated per pound of coal is concerned, is mostly due to the characteristics of the apparatus, its manipulation, and to the size of the coal and the amount of ash associated with it.

Thus it is very clear that specification or guarantees covering amount of evaporation per pound of fuel or percent efficiency, are not only useless but troublesome to the purchaser and dealer.

The three approved tests may now be considered, and while in the above classification they are presented in the order of greatest importance, it will be convenient to change their arrangement.

## PURE COAL.

For better understanding, it is desirable to consider coal as the chemical combination of certain elements which are principally

*Journal, W. S. E., XI, p. 529, Oct., 1906

heat producing. The association of ash and moisture with these, results in an aggregation which may be designated as fuel, although generally called coal, which, from this standpoint, however, is not correct, because neither ash nor moisture produce heat.† The expression, pure coal, is the equivalent of what has erroneously been called combustible, the pure coal containing all of the combustible matter, and some water of composition and nitrogen which are not combustible, but as these two ingredients are associated chemically with the combustible, the ultimate conception of coal is covered by this term, pure coal. Thus in the heating power determination, it is more to the point to base results on the pure coal than on any of the fuel mixtures, illustrated as follows:— Let it be assumed that in one case the B. t. u. per pound of dry coal is 13,250, and in another 12,450, from which it would appear that the two lots of fuel were different, but if the ash content in each is known, and the first sample contained 7 percent and the latter 12 percent, it appears that each sample has a pure B. t. u. of 14,250, or, in other words, that the coal is the same in each, there simply being more ash associated with it in one case than the other. Basing the heating power determination on pure coal has another very important advantage, it enables one to judge of the accuracy of analysis, because when the heating power and the source from which the coal comes is known, there is evidence indicating whether or not the analysis has been correctly performed, because, if it has not been, it will be shown by the B. t. u.

## ASH.

An important reason why ash should always be considered as a percentage of the dry coal instead of the moist fuel, is, that like the B. t. u. determination, unless it is placed on some common basis, proper comparison cannot be made on different lots of fuel; for example, in two samples, the moisture may be 8 and 13 percent and ash in the dry coal 10 percent in each, but expressed on the moist coal basis, it appears that one has 8.7 and the other 9.2 percent of ash, and it would seem that one of the fuels contained more than the other. In this connection the fact should be borne in mind, that no one burns moist coal; the moisture is evaporated and passes away; in fact, dry coal is not burned, the ash remaining; it being the pure coal which enters into the process of making fire.

## SIZE OF COAL.

As a general proposition, the value of fuel increases with the size of the pieces, so that a very fine "duff" is of little use, but as the pieces become larger, the actual value increases in a greater

*Journal of Am. Chi. Soc., Vol. 28, p. 632.

ratio than does the heating power, and this continues to egg size and lump. Thus smaller pieces containing the same amount of heat per pound as larger ones, are of less value than the larger coal.*

The size of the pieces of coal exercise an important influence, not only on the capacity which may be produced by a boiler, but on the resulting efficiency, and the best size to be used in a given case is dependant upon many conditions, such as the strength of draft, kind of stoker or grates, method of firing, etc., and the selection of the proper size of fuel or the method of utilizing the available size, often affords an opportunity to effect important economies.

### SAMPLING.

One feature of the matter, referring especially to coal inspection service, is proper and reliable sampling. In very many cases the coal inspection service is rendered by a company, which, while acting as the purchaser's representative, is depended upon to furnish the seller with reliable reports concerning the composition of coal supplied. Under such conditions it is absolutely necessary that not only shall the inspecting chemist be both competent and reliable, but that he shall be as fully responsible for the collection of the samples as he is for the analytical report, and it is also absolutely essential that the purchaser or his employés shall not be allowed to sample any coal or assist in the sampling, because under such conditions, the chemist may not know whether the report which he makes is correct or not, and it is well to emphasize the fact that the sampling is of as great importance as that of the analysis itself.

Referring to the branch of the subject before mentioned as that of research, there has been in operation for some years at St. Louis, what has ben designated as a fuel testing plant, under the direction of the United States Geological Survey. Its principal published work so far, however, has been largely confined to "tests" under boilers, which have been thought to show the "real steaming value" of the fuel. The author's remarks above regarding testing coal under boilers, will refer to this branch of the work.

Probably the reference to coal in the plural has done much to cause confusion, because it has led people to believe that there are very many "kinds" of coal. For example, fuel from Herrin and Carterville in this state, would, according to this, be considered as different "coals" when, as a matter of fact, they are from the same seam, and the most exact analytical tests so far made, do not indicate a difference. The amount of ash associated with the coal may or may not vary, but the coal is the same, and it is coal and not coals, otherwise, every mine would produce a different kind of coal, notwithstanding the fact that seams in Illinois sometimes run through an entire county without it being possible to

* Journal. W. S. E., XI, p. 529, Oct., 1906.

detect any variation in the quality; therefore, the expression, kinds of coal, which has been used frequently, in connection with coal testing work, should not only be better defined, but limited in its application to those cases where there is a real difference, which, as is well known, does exist; for example, it must be conceded that anthracite and bituminous are different kinds of coal, but the most liberal application to this coal basin would allow only two kinds, which are the block coal of Indiana, all the remainder being bituminous, the latter also including what is known as semi-block of Indiana.

The state of Illinois has made an appropriation covering cost of investigations to be conducted by the Engineering Experiment Station of the University of Illinois, and there is certain important work which it is hoped will be undertaken, having a bearing on the values of fuel, studies tending to define the laws controlling the influence due to the size when burned with some different kinds of stokers or grates, and similar studies to ascertain corresponding effect due to varying amounts of ash in coal, also degree of fusibility of such ash.

The recently established State Geological Survey will present by all means a very much better coal report than has so far been published by any state, and it will be a great help to the purchasers and producers of coal, if certain values as affecting heating power, ash and moisture are authoritatively presented. As before mentioned, the three essential items are heating power of the pure coal, percentage of ash in the dry coal and moisture. The B. t. u. values would be the simplest of the three, as these results would apply to pure coal, and which is, no doubt, practically a constant for a particularly locality of a seam, therefore, once determined, it will not be necessary to repeat tests. Establishing ash values would be a more difficult matter, because it would not only involve ash in seams as the coal lies in the ground, but the various grades of fuel shipped from those seams. Ash, however, at the mine, would be the same in quantity as when received by the consumer. Securing moisture values would be a far more complicated problem, because of greater variation due to temperature, weather conditions and time in transit. For these reasons, it is difficult to arrive at any conclusion regarding the amount of work which may be justified in the establishment of such values. Some idea of the complication may be illustrated; for example,—the washed and sized coal shipped so extensively from Williamson County has a characteristic moisture content due to the difference in the size of the pieces, the larger ones being drier, and these moisture contents vary over wide ranges between summer and winter, and also according to the length of haul; thus at least average moisture values would be needed for each size, at the city where the coal was received.

A recent expression which has come into use, is that of "air-

dried coal", which is based upon allowing the sample to become dried in the open air of the laboratory, the idea being that this shows the fuel as it would reach the customer. No standard conditions, however, appear to be employed in this air-drying, and if there were, the values obtained thereby do not indicate the amount of moisture in coal when it reaches the consumer. Some samples of air-drying on Illinois coal have shown the moisture as being between 5 and 6 percent, when as a matter of fact, the same coal is never received with less than 7, and in the winter time it is very much more. This moisture value should be abandoned, as it serves no useful purpose, tending only to increase existing confusion and misunderstanding.

## Discussion.

*Mr. W. L. Abbott*—(M. W. S. E.)—(Chairman)—The matter of investigation of Illinois coals was considered not long ago by a gentleman who is in this room. I think it was his work along this line whch has attracted the great interest which has recently been shown in this work. I think that it is true he has probably done more work in making analyses of western coals than any one else, and it was certainly his work in producing the Parr calorimeter which has put this coal testing business upon a practical and feasible basis. I take pleasure in calling upon S. W. Parr, Professor of Applied Chemistry at the University of Illinois.

*Professor S. W. Parr*—I think it takes some courage for a chemist to come before an audience like this and try to talk about matters that are of special interest to engineers. I think sometimes the more I study the question of coal, the less I know about it. There are two impressions that strike me forcibly at this time; one is that when Mr. Bement has thought out a subject to a point where he is willing to talk, he is very likely to be about right; the other is that after he is through talking there is not much more to be said. So I hardly feel that I can add anything to the admirable discussion of the topic which he has given us. I think there is a misconception on the part of the engineers in regard to the chemist's position as to moisture. It seems ncessary for accurate work for the chemist to start out with the coal in that condition which will be least affected by the condition of the atmosphere. If he starts with coal that has been oven dried, the sample will be constantly undergoing change by absorption of moisture. If, on the contrary, the initial condition of the sample is one wherein an excess of moisture is present, his sample and his weighings are constantly changing by reason of a loss of moisture. He therefore tries to bring his sample into the condition which will most nearly correspond to the average hygroscopic state of the atmosphere. It would seem from this statement therefore that a determination of moisture in the sample as the chemist must work with it, is essential in order to

arrive at any other condition which might be prescribed by the engineer.

Concerning the constituent which is discussed in the paper as pure coal: I think a criticism may be applied to it in that it is likely to be used as a unit of comparison. The pure coal of one region certainly has no direct relation to the pure coal of another locality. I am aware that it is intended to refer only to the particular vein in connection with which the term may be used, but it may be a question as to whether the pure coal from the same vein may be always the same. Take for illustration a coal with 10 per cent of ash. Now, a sample of screenings from the same vein may have 20 per cent of ash, the additional 10 per cent being made up of shale or fire clay. Suppose I take this shale and treat it separately as in the proximate analysis of coal and I find say 15 per cent of volatile matter. Now, when the coal itself is analysed with this addition of clayey constituent it goes through the same changes and adds to the credit of the pure coal this extra volatile matter which is not present in the sample where the clay is absent, and our pure coal factor varies in proportion. Similarly, in the matter of sulphur; by the processes of analysis a fraction of the constituent which should be credited to pure coal is taken from it by replacement of oxygen in the ash for sulphur, and we have here an error in the opposite direction. It may be that these two errors balance each other, and the ultimate result is satisfactory from the engineers' standpoint, but chemically, it seems to me open to criticism.

If our analytical methods furnished us with a fuel unit which would be comparable, one coal with another, one region with another, and especially, the same coal with itself, it would be greatly to our advantage. For, example, the constituents in a coal that will actually burn are carbon, hydrogen and sulphur, and the sum of their respective percentages would be an actual fuel unit which could be compared between different coals, but no ready method of analysis gives us these constituents. So I feel sometimes as though we had started at the wrong end, and have been producing analytical results of little value. In this respect therefore I am in harmony with the author of the paper.

One other constituent, it seems to me, would be found to have value from an engineering standpoint, and that is the ratio between the carbon of the volatile hydrocarbons and the total carbon. This ratio, for example, in Pocahontas coal expressed in per cent. is 12; in certain West Virginia coals it is 20; in a very few Illinois coals it is 21 and 22; in more Illinois coals it is 30. This bears no relation to a ratio which has sometimes been developed between the volatile matter as ordinarily determined, and the fixed carbon. I believe that for every per cent. of variation in these pure carbon ratios a different condition as to draft, combustion chamber, bridge wall, etc., would be found desirable, and it is this ratio which fur-

nishes the chief means for interpreting the differences between the various types of coal. It would be too long a story for me to enter into this proposition at this time but I think we would do well to consider the matter. This is merely a suggestion of some of the things we have yet to find out, and I am sure that if they prove to have anything of interest to the engineers the chemists will take every opportunity to furnish the necessary data for getting at the problem.

*Mr. Abbott*—Mr. Bement, in his paper, is nothing if not original. He is never so happy as when taking a tilt at some one, unless it is when some of the sponsors of some of these theories are taking a tilt at him. He took occasion to throw a brick or two at the United States Geological Survey's fuel testing plant at St. Louis. I will ask the engineer in charge of the Boiler Division of this Testing Plant to return the bricks.

*Prof. L. P. Breckenridge*—(M. W. S. E.)—It would seem as though the United States Geological Survey's boiler division would know when a brick was thrown at it, but the brick must have been soft and did not hit very hard, so that the Survey hardly realized that a brick had been thrown.

However, there are some things that the speaker would like to bring up, in connection with this paper, either as Engineer in charge of the Boiler Division, of the United States Geological Survey, or as Director of the Engineering Experiment Station at the University of Illinois.

I feel like saying first that we are to be congratulated on the presentation of this paper, containing as it does new matter,—new things to think about. We are to be congratulated particularly on the large amount of discussion which has been sent in,—written discussion. I frequently think that written discussion amounts to something, while talk seldom does. After the written discussion which has been presented, and the ground covered by the paper itself, if we confine our remarks to the lines indicated by the paper, there certainly is not much more to be said.

I am very much pleased at the interest indicated by the discussions which have been presented, many of the thoughts which have been suggested could not apply if the writers had confined their attention to the Eastern Interior coal basin, as Mr. Bement said he was trying to do.

I believe I have not thrown the brick yet, and the remarks I have been making are all bouquets. There is really only one brick to throw and that is this: I would criticise the title of the paper. I think the title was written before the paper. That is always unsafe. The paper should be written first, and then a title given to it afterwards. I do not like this title—"The Testing of Coal." It does not indicate what is in the paper. It seems to me a better title would be "Characteristic Properties of Coal of Importance to the Consumer." This means just what the paper has discussed,

but the Testing of Coal is a broad term, and you would hardly know what might come under that head.

The practice of wetting coal before burning has always been an important subject for debate, but I hardly feel like taking that matter up at this time.

I thoroughly agree with the author in his remarks under the heading of "Evaporative Power," where he states:

> "This is something which should never, under any circumstances, become a feature of specifications or guarantees, for several very important reasons. In general, too many variable factors enter into the problem. For example, boilers differ, some being more efficient than others. . . . Then furnaces differ greatly; in some cases all of the volatile matter may be burned; in others, a large portion may be wasted. Again, fire grates differ," etc.

I think we would all agree on that proposition.

The term "pure coal" is rather a new one, and I think I like it. Of course the chemists point out various objections to this, and I can easily see that out of all of this we may sometime arrive at a common agreement of what we will call things. It seems, though, that the term "pure coal" is a good one in this connection, and it seems to be quite well defined in this paper.

Under the head "Size of Coal" the author gives several reasons why it would be well to make boiler tests. Of course, to people who are well versed in the whole subject of boiler testing, and who have made many boiler tests (and so many are poorly made) there is a tendency to say it is not worth while. It *is* worth while. Poorly made trials are not worth while, as you will agree. But suppose you make a boiler trial as well as the United States Geological Survey makes its tests today; if you make one as well as that, it includes all the information that any of you may desire. That is one reason why it would pay to make the test. I believe that, taken in connection with the other tests being made with the fuel, it justifies the work being done when we consider the elaborateness or the care with which these tests are being made.

Again, the author says:

> "Referring to the branch of the subject before mentioned as that of research, there has been in operation for some years at St. Louis, what has been designated as a fuel testing plant, under the direction of the United States Geological Survey. Its principal published work so far, however, has been largely confined to 'tests' under boilers, which have been thought to show the 'real steaming value' of the fuel."

I notice some quotations in that paragraph, and I am inclined to think that the publicity branch of that Bureau is not altogether discreet in the use of terms, and says thing which the scientific branch of the Bureau would not advise. However, I think the author conevys an erroneous idea when he says that this work has

been confined to tests under boilers. This is by no means the case. The work of the gas producer division is a very important one at the fuel testing plant. If it were necessary to prove that the work was of some value, I might say that, in order to demonstrate the possibility of utilizing western coal—Illinois coal—certain trials have been made in gas producers and gas engines, continuing for 25 days, continuous operation for 24 hours, producing 220 H.P. on approximately 2 lbs. of coal per horse-power hour, with Illinois coal. It seems that almost any coal can be used in a gas producer, even though the coal contains a high percentage of sulphur. All this is very valuable work and is outside entirely of the work done by the Boiler Division.

Much useful work has been done to determine the conditions under which coal should be coked, and by certain mixtures of small percentages of others coals detemined by analysis, very successful operations have ben carried on, whereby Illinois coals have been made into satisfactory coke.

Many samples of coal from different states have been briquetted, demonstrating the cost and feasibility of briquetting, and I am sure the impression ought not to be made that this public work has been largely confined to tests under boilers. I am sure the Boiler Division does not want all of that credit.

The State of Illinois has made preparation for carrying on experiments of value to the industries of the state of Illinois, and there has been established an Experiment Station at the State University. One of the things this Station has been doing is the carrying on of some tests with fuel. The Director of the Experiment Station, in order not to make too many mistakes and in order to get the advice and support of as many interests as possible, has asked six or seven of the industrial organizations of the state to appoint a representative to act as a member of a Conference Committee to meet with the Director and discuss these subjects. The Western Society of Engineers, the Western Railway Club, Illinois Coal Operators' Association, Illinois Manufacturers' Association, Illinois Electric Light Association, Chicago Building Managers' Association, and the State Geological Survey, have each appointed a representative. These different representatives will from time to time meet and advise with the Director about these tests, and the tests which will be made will doubtless be the composite opinion of all these various Associations. After consultation, the Director will try to focus the general concensus of opinion into some plan which will be carried out. The plant is now in operation and tests are being made, and I should like to say that the Director of the Station will be glad to have suggestions relating to tests of fuel reach him, in order that any thoughts that come to you may eventually be provided for in the work of the Station.

One of the principal lines of work which we will take up will be experiments with washed coal; the question as to its compara-

tive economy, washed and unwashed, its freedom from smoke, and various problems relating to that whole subject. This, however, is a trifle foreign to the general subject under discussion.

If I had time I should like to point out that the interest of the producer goes far beyond the character of the coal as discussed in this paper, but it is true. The thing necessary in an individual power plant is to keep up steam. The next thing is to do it with as little money as possible. You might select coal according to the Abbott-Bement scale, and you might furnish this coal to ten plants in this city; what would be the result? One plant would get an evaporation of perhaps 5½ pounds of water to 1 pound of coal; another might get 8½ pounds of water to 1 pound of coal. Why the difference in these results? This brings up many thoughts in connection with the subject, but I can not take more of your time tonight.

*Mr. Abbott*—Among the distinguished visitors here to-night is a gentleman from whom this society is expecting a great deal along this line, because, although he may not know it, the Society helped him to get his position. I refer to the fact that, less than two years ago, this Society petitioned the State Legislature to institute a Geological Survey of this State. As a result of that petition and other influences such a Survey was authorized, and we now have with us the Director of the Survey.

*Dr. H. Foster Bain*—(M. W. S. E.)—I want to thank the Society for the interest taken in getting the Survey started, for I think it is a good thing for the State. The Geological Survey is interested in coal, and I think our interest coincides with yours. We are very glad indeed that such discussion as that of to-night is to be had, and we are also glad that such work as that mentioned in the paper is being carried on. Our own problems are centered more upon the distribution of the coal and its character, but in order to make the greatest use of that information we must know how that coal can be used and where it can be sold.

In the discussion of this evening it seems to me there is a concensus of opinion on certain points, and on others a disagreement. One of the latter is with regard to the testing of moisture in coal. There are two points of view—that of the man engaged in research and the man who is engaged as Inspector. From the first point of view there is no more interesting subject than that of moisture in coal. We are now engaged in certain studies which we hope will some time clear up certain of the difficulties. The Inspector is, however, concerned only with the present and where and how to properly apportion the cost of a varying moisture content. To me there is a certain amount of inequity in throwing upon the purchaser of coal altogether these differences in moisture, and I think there should be a given standard. The moisture content as mined is certainly one important thing to be determined, and it is possible that in that determination we may find a standard

that can be used all along the line. From it, possibly a set of specifications for buying coal may be worked out. As a first step we are now having the coal beds of the state sampled. In all 160 samples have been taken, and we hope to have a great many more, all taken by a uniform system. We do not know everything this will lead to, but expect Professor Parr to turn over a number of interesting and valuable results. At a later time I hope to tell the Society more about the work of the Survey. In the meantime we want to have your continued interest in the Survey and your help in the progress of the work.

*Mr. Abbott*—So far this work has been discussed by academists. We would like to hear how the man who sells the coal would like to have it sampled. I will call on Mr. Rice.

*Mr. Geo. S. Rice*—(M. W. S. E.)—I feel somewhat reluctant to speak, because I am uncertain what is best to do. As a Mining Engineer I am called upon to sample coal in various parts of the country, and of course a wide difference is found in the constitution of coals, particularly in the amount of moisture contained as well as combined; and after many years of practice I feel uncertain what is the best way to sample, and, so far as moisture is concerned, to test the sample. I am in great hope that our new Illinois Geological Survey will be able to discover some things which will have a bearing on these questions.

As regards the chemical part, I have done some analytical work in the past and have also sent work out to chemists, and have found a wide diversity in results with the same coal, sampled in the same way; different ratios of volatile matter and fixed carbon; in some cases, with the same coal, the fixed carbon was reported more per cent. than the volatile matter, other chemists reporting reversely. I do not think these discrepancies ought to be; we must expect our chemists to standardize better in making proximate analyses. One uncertainty in their present methods is the size and heating power of the flame used in volatilization. There is also something that the present chemical analysis does not reach at all, either in the proximate or ultimate analysis; namely, what constitutes the coking property of a coal. There has been some attempt made to group coals on the basis of moisture contents and to separate lignites from bituminous coals on this classification. While this works with brown and peaty coals, it does not always do so with other lignites. Take such a high-grade lignite coal as that found near Gallup, New Mexico; a jet black coal which has only about 10 per cent. of moisture as ordinarily produced from a dry mine. Compare that with an analysis of middle west bituminous coal and you are not able to detect the lignite; then watch the performance—a Santa Fe engine climbing a grade—and you will see a line of sparks twice the length of the train. I think we ought to find out what that peculiar difference is. The coal as it progresses from the lignite to the bituminous stage appears to go

through some geologic process the result of which is not detected by present methods of analysis. If we could solve that point we could perhaps determine better the probable ratio of the volatile matter and fixer carbon. That ratio is an important thing in a fuel; that is, I think the chemical combinations of the carbon are important. Certainly there are many coals which seem to agree very closely in chemical composition, in which there is quite a difference in their heating power in the same furnace, irrespective of the moisture. It makes a very uncertain factor in judging the value of a fuel from an analysis.

Returning to the question of moisture; that is something we ought not to neglect or leave out in our account. Here in Chicago we are burning coal from a great many sources—West Virginia coal; bituminous coals of Pennsylvania; Hocking Valley coal, and finally the Illinois coals. These all differ widely in moisture contents. To apply a scheme like Mr. Bement's there should be some uniform method of analytical reporting that will apply not only to the coals of Illinois, but to the competitive coals. We miners have to meet that competition right along. There was a time when the northern fields of Illinois were shipping coal extensively to Chicago,—now their lump coal hardly enters Chicago at all; it goes toward the northwest. The bearing of this is, that here it is being supplanted by eastern coals, sometimes irrespective of price. I think any scheme of buying and selling on an analytical basis should seek a standardization of the whole thing, particularly as the matter seems to be of wide-spread interest throughout the country.

Mr. Bement has touched on the importance of size of the coal as used in a boiler furnace. Unfortunately I was not present at the recent meeting when Mr. Abbott presented an able paper, which treated this subject, and I did not have the advantage of the discussion. Mr. Bement speaks about the fine coal or "duff" being of little use. It would seem to me that that is rather contradictory to the scheme he presents in which one of the elements is to be pure coal. You can have a "duff" that is very pure, particularly if well washed and if burned under right conditions it ought to give good results. We are using washed duff, under ¼-in. diam., exclusively at our Cardiff plant of five boilers. The difference in quality of fine unwashed screenings depends somewhat on what mining conditions may prevail. When the roof stratum is shaley or the bottom is fire clay and soft, pieces of roof or fire clay are shoveled up with the coal. This makes the fine coal of little value unless it is washed. On the other hand where the roof is strong and there is a hard, smooth floor the coal can be shoveled up cleanly and then the fine coal is undoubtedly of value and a good efficiency can be obtained from it if burned properly and on suitable grates. It therefore appears to me that it will not be safe to generalize that fine screenings are valueless as fuel.

Returning to the matter of sampling, I very much doubt if it is safe for a consumer to assume that he can judge of the percentage of ash from knowing the characteristic ash of a given field or mine. The matter of preparation of the coal, by the miner below and the picker on top, or manipulation of the washery, or even the division of the screenings can make a difference of several per cent. of ash in the coal as delivered to the customer. We who produce know we frequently are obliged to have a house-cleaning to keep the loaders and pickers at the mine up to the mark. For these reasons I do not advocate dropping the figures for ash from the exhibit of the analysis. The same reasoning applies with even greater force to the sulphur determination, and I therefore think this also should be included in the exhibit.

On the whole it appears to me that, able and clear as Mr. Bement's presentation is, it is not less information that should be reported of a given sample of coal, but more.

*Mr. P. C. McArdle*—(M. W. S. E.)—I do not know whether Mr. Bement had bricks to throw at others than Prof Breckenridge, but one of the first five elements he proposes to drop seems to strike home to the City of Chicago. The City of Chicago is engaged in testing coals by the evaporative as well as by the B. t. u. method. Our specifications demand a guarantee of evaporation, volatile matter, fixed carbon, sulphur, ash, moisture and B. t. u. based on dry coal. We are taking care of the evaporation tests as well as the B. t. u. determinations which is a big job. So far this year we have no great reason to complain of evaporative tests.

I have changed my mind about the value of evaporation tests. The evaporation results up to this point compared with the approximate analysis agree so closely that there is very slight difference. Of course the differences vary with the different furnaces; each furnace differs in its construction and in its burning of coal, but generally the good modern furnace burns the coal in such manner that the results approximate very closely to the value yielded by the calorimeter, due consideration being given to boiler efficiency.

In the matter of presence of moisture in dry coal, I agree with the author, but I do not quite agree with his pure coal proposition. That will lead to considerable inaccuracies if we are to tabulate bids on this basis. Coal containing a large percentage of ash will necessarily give a higher result, than one having a lower percentage of ash. However, in comparing the values of coal from one seam or one vein I think the author's ideas are well taken.

I have found in the matter of the size of coal what Mr. Bement states is a practical opportunity for economy, except in this,—that on the chain-grate furnace efficiency will drop after a certain size is reached. If the size goes over 1 in. there is a large amount of waste over a chain grate. With a chain grate, as described in the previous paper, the best sizes are from 1 in. down to ¼ in., but if you go above ¾ in. a large amount of the coal goes down unburned

into the ash basin. However, that is not true of other styles of furnaces.

In the matter of sampling I am in entire accord with the author.

*Mr. E. H. Cheney*—(Fuel Engineering Co.)—I agree heartily with the author on the points brought out in his paper, with the following exceptions:

I do not believe that the determination of moisture should be abandoned. It is to my mind quite evident that the author is treating his subject from the point of view of the coal dealer, and the reasons that he advances as arguments why moisture should be dropped, seem to me the best possible arguments why, speaking from the consumer's point of view, the determination of moisture should not be dropped. No one disputes the fact that the moisture in coal adds nothing to the heating power of the coal, but on the contrary detracts from the same to the extent of the heat required to raise the water content to the temperature of the flue gases, and as coal contains from 3 per cent. moisture for Eastern coals, to an average of 10 per cent. for Illinois coals, the item of moisture is not a negligible one. All specifications should, therefore, in my judgment, stipulate the amount of allowable moisture, and proper penalty should be fixed for delivery in excess of the amount allowed and a corresponding bonus paid for delivery of less than contract amount.

The fact that the dealer has no control over the elements is, in my mind, no reason why he should be excused for delivering an excessive quantity of moisture, but should be considered as one of the unfortunate conditions existing in his particular line of business.

Under the subject, "Size of Coal," Mr. Bement states that the actual value, which I understand to mean heat value of coal, increases with the size of the coal, even to the egg and lump sizes, and refers to Mr. Abbott's paper of September 5th as his authority. While I agree with Mr. Abbott's paper as demonstrating this to be true in screenings burned upon a chain grate, in my experience, this is not carried out to the extent that Mr. Bement indicates in the larger sizes of coal, and I am inclined to believe that investigations will show that such is not the case. I think this a subject well worth study and would like to hear further from Mr. Bement with regard especially to the relative value of the larger sizes such as egg and lump as compared with the smaller sizes of sized coal.

DISCUSSION. CONTRIBUTED BY LETTER.

*Dr. W. A. Noyes*—(National Bureau of Standards, Washington, D. C.)—I am inclined to agree in regard to the determination of volatile matter and fixed carbon, though Dr. C. B. Dudley has said to me a number of times that for their locomotive service they find that a certain ratio between these constitutents gives bet-

ter results than either a higher or lower ratio and it may well be that users of coal who have made a careful study of the matter may find it to their advantage to use a coal with a certain specified ratio between the two constituents.

As regards moisture it appears to me that the determination is a very imporant one since different coals vary from one to two per cent. for the bituminous coals of the Pittsburg region to more than twenty per cent. for some of the lignites of the West, and the value of the coal will evidently vary by the same amount. It is of course imperative that the sample should be so taken as to represent the true moisture content of the coal. An article which will appear in the November number of the *Journal* of the American Chemical Society emphasizes the need of a much greater care than is customary for the determination of moisture.

Since the moisture varied so greatly according to the statement the heat of combustion for the pure coal of Illinois seams very rarely varies as much as two per cent. from the mean, it would seem that moisture determination is very much more important than the the determination of heat of combustion. Also, since sulphur varies in these coals from less than one per cent. to five per cent. or more and the heat of combustion of sulphur is only about one-fourth of that for the rest of the coal, it would seem that the sulphur determination has considerable importance.

Since in the determination of ash the sulphur either disappears entirely or is replaced by three-eighths of its weight of oxygen, the ordinary analysis reports a considerable portion, at least, of the sulphur as pure coal. For this reason and because of the lower heating value of the sulphur, our Committee on Coal Analysis recommended that the true combustible of coal, or as the author calls it, the "pure coal," is best calculated by subtracting from 100 the moisture, ash and one-half the weight of the sulphur. If users of coal would purchase on the basis of the per cent. of pure coal calculated by this formula, I should suppose that for most fuel purposes no other specification than the amounts of moisture, ash and sulphur would be required.

*Prof. Wm. Kent*—(Syracuse, N. Y.)—I agree with Mr. Bement in most of his general propositions but would suggest a modification of his scheme for valuing coal by adding to his list of three requirements, viz.: per cent. of ash in the dry coal, size of the coal, heating power of the pure coal, a fourth, namely, moisture in the air-dried coal.

After drying a sample of coal by exposing it to the atmosphere of a room at ordinary temperatures, it will be found on proximate analysis to contain a certain amount of moisture which is characteristic of the coal itself and is independent of any accidental wetting it may have received. This moisture is just as much a property of the coal as is the fixed carbon, the volatile matter, or the heating value of the pure coal, and it varies in coals of dif-

ferent localities of the Western states to such an extent that next to ash it is the most important constituent affecting the available or commercial heating value of these coals.

Mr. Bement says that the heating value of the pure coal in Illinois ranges only from 14,000 to 14,705 B. t. u. per lb., but the St. Louis tests show a range in six samples of from 13,767 (No. 2) to 14,674 (No. 3). This range, however, is less than 7 per cent. while the heating value of two of these six coals, Nos. 3 and 4, exclusive of ash but including the moisture left after air-drying, differs nearly ten per cent.

The following are the data of these two coals (laboratory car sample, air dried).

| | No. 3 Marion Co. | No. 4 Belleville Field. |
|---|---|---|
| Moisture | 5.96 | 11.40 |
| Volatile matter | 30.29 | 32.45 |
| Fixer carbon | 52.16 | 44.30 |
| Ash | 11.59 | 11.85 |
| Sulphur | 1.77 | 1.34 |
| Heating value by calorimeter | 12,102. | 10,991. |
| Calculated from ultimate analysis | 11,907. | 10,912. |
| Heating value of pure coal | 14,679. | 14,321. |
| Heating value of coal free from ash | 13,689. | 12,469. |

The difference in heating value of the two coals free from ash is 1,220 B. t. u. or 9.8 per cent. of the lower value. The air drying of these coals was done on samples crushed to about one-fourth inch size, exposing to the air for twenty four hours, or until the loss of weight on further exposure becomes slight.

By Mr. Bement's method of valuing these coals, No. 3 would have a value represented by 14,679x (100—11.59)=12,978; and No. 4: 14,321x (100—11,85)=12,624, a difference of 354, or less than three per cent. while the actual difference of the heating value of the air-dried coal (the coal actually used by the consumers if the surface moisture is dried out of it by long exposure under cover), is 12,103—10,991=1,112 B. t. u., or 10.17 of the lower value, a greater difference than exists in the whole range of heating values of pure coal thoughout the state.

The real commercial values of these two coals, however, differ by a far greater figure than 10 per cent. In the use of the coal No. 4 under a boiler, 5.44 lbs. more of water per 100 lbs. of coal has to be evaporated from the coal (as compared with No. 3), before it begins to distil its volatile matter. This water not only has to be evaporated, cooling the fire, but some of it may be decomposed, forming water gas, a further chilling operation, and if the coal is of fine size, choking the air supply, some gas may escape

being burned in the furnace and pass off as unburned gas, especially if the furnace is of the ordinary anthracite type commonly used under water tube boilers in the West.

For these reasons I would specify as one of the items on which Illinois and other western coals are to be valued the moisture contained in the coal after exposing a sample crushed to ¼-inch size to the ordinary air of a room for 24 hours. In my book on Steam Boiler Economy, p. 51, I proposed the following specifications for semi-bituminous and bituminous coal:

> "The standard is a semi-bituminous coal containing not over 20 per cent, volatile matter, 2 per cent. moisture, 6 per cent ash. A reduction of 1 per cent. in the price will be made for each 1 per cent of volatile matter in excess of 25 per cent. and of 2 per cent, for each 1 per cent. of ash and moisture in excess of the standard."

For Illinois coals something like the following should be adopted:

> The standard coal is one containing 14,500 B. t. u. per lb. of pure coal, not over 6 per cent. moisture and 10 per cent. ash in an air-dried sample. For lower heating value per lb. of pure coal the price shall be reduced proportionately, and for every 1 per cent. increase in ash or moisture above the specified figures, 2 per cent. in the price shall be deducted.

*Mr. Wm. M. Booth*—Upon many of the points under discussion I have expressed myself in the article, "How Should Steam Coal be Purchased," published in the Engineering Record of September 22nd. In addition I may add:

Although manufacturers are now anxious to make their purchases according to specification, they are at a loss to know how to specify. The conditions in New York state are peculiar. We receive coal that varies in quality from the poorest grade of slack to a first-class bituminous coal of high heating power, low in ash, and burning with but little smoke. The price does not always fix the value of the coal and where this commodity is purchased by contract, one consignment may be of average grade while the next may be very poor. It is a fact that dealers furnish coal from many sources, irrespective of the conditions at the plants of their customers. To this practice I am very much opposed.

After the coal fields have been thoroughly investigated from an analytical standpoint, coal from certain mines may be specified and from other mines avoided. Unscrupulous brokers are making every attempt to sell poor coal, while the best coal dealers are anxious to obtain a coal low in ash, and free from slate. I understand that it does not pay operators of mines to produce a high slate coal.

Referring to the paper: Moisture is the least of our difficulties as it is usually low, rarely rising above 2 per cent. In the case of a coal containing 6 per cent moisture or higher, it would seem that this would become a more important matter.

The volatile hydrocarbons of coal shipped to Syracuse run from

18 to 45 per cent. This at the outset condemns coal of the latter grade when burned under the ordinary boiler. In fact this particular sample of coal is called a poor grade, although it contains more than 15,000 heat units per pound.

Regarding sulphur: While not sure that the present method for obtaining sulphur is the best, I believe that attention should be paid to this element, or that more attention should be paid to the composition of the ash. A fusible slag requires silica with various oxides; calcium, magnesium, iron and aluminum furnishing the bases. Ferrous sulphide (the decomposition product of pyrites), in contact with steam at a high temperature must partially break up forming ferrous oxide. This compound is then ready to unite with silica to form a fusible slag.

I have found an appreciable amount of manganese in many samples of coal. Of its effect in connection with the ash, I have no positive knowledge nor do I know that its presence works injury to the fuel. But from the effect of the various oxides mentioned, in connection with other industries I am quite sure that a fusible clinker must result if large quantities of silica, oxides and sulphides are present. If the ash of coal from a particular mine is fairly uniform, its properties may be determined, and the coal set down as a clinkering or non-clinkering grade. I thoroughly agree with Mr. Bement in reference to the evaporative power of coal, and am opposed to tests that pretend to determine this feature. It is at best approximate, and the dealer is liable to be the loser, as any new sample of coal requires new methods of handling, which firemen for months after, fail to understand.

A great deal of prejudice exists in the boiler and engine room of most of our concerns, and very good coals may be given very careless tests.

Regarding the portion of the paper entitled, "Pure Coal," I have not formed a definite conclusion, and therefore shall have to pass this by.

Mr. Abbott's paper dealing with the size of coal shows the importance of this feature, and I think that the subject should be investigated further.

Regarding the sampling of coal, I wish to say that the results of chemists may appear ridiculous if this feature is not carefully considered. Two samples of coal were taken from a dealer recently, and one was brought to my laboratory and one was carried to the laboratory of a steel concern. These samples were supposed to be identical. The ash in one case was found to be 8 per cent., and in my own case 12 per cent. were found; while the sulphur of the sample taken by the steel company was reported 1.3 per cent. and sample taken by me, analyzed in duplicate, proved to be 1.6 per cent. Our methods of analysis were identical. I fully agree that the sampling is of as great importance as the analysis.

One more matter,—the fireman is not capable of taking samples

nor should he be allowed to do so. Recently I asked a fireman to get up samples for analysis. He immediately searched one pile for the best piece of coal and the next for the poorest; remarking, this is "good coal," and that is "bad coal." The analysis of average samples failed to show a large difference.

My clients are much interested in the ash of coal, as this appears on the wrong side of the ledger twice. First, because of its lack of fuel value, and second, the expense of its removal. After this, the possible heating value of the fuel is of interest to them. While not familiar with the absolute term "B. t. u." the relative values of two coals differing in B. t. u. by 1,000 units per pound and expressed for one ton are obvious to the average superintendent. An ultimate analysis is expressed in chemical terms, and therefore entirely beyond his comprehension. From a scientific standpoint I consider such an analysis of primary importance. The proximate analysis has been, and *is* a standard form for determinating the value of coal and while the sulphur and volatile matter are not definitely understood, knowledge of the ash, water and total carbon are of great importance even to the ordinary engineer and operator of a steam plant. I believe that public opinion should not be shaken in reference to specifications if operators are just ready to receive the proximate analysis in connection with the purchase of coal. This form of analysis, while not being chemically accurate, is valuable in determining the grade of coal. Where this material is sent from thirty or forty sources, it seems that it would be difficult to eliminate the determination of volatile matter when considering the value of the fuel.

I cannot speak too highly of calorimetric tests of coal. Large operators should have such made often, along with flue gas analysis.

As soon as fuel engineers impress coal users with the importance of analyses of coal and its products they will be ready for easily understood data. I know of nothing more direct than the report of moisture, ash and B. t. u., nor more easily interpreted by the chemist than a proximate analysis with more data regarding the constituents of the ash.

*Mr. W. F. Cooper*—(Michigan Geological Survey)—Being more than anything else a stratigraphical geologist and not so very much of a chemist I will have to admit inability to further very much the discussion of this important matter. However, having just produced a report on the geology of Bay county, Michigan, from which very nearly half of our coal is mined, and during the course of which a large amount of information was obtained concerning the stratigraphy and chemical value of the different coals were obtained.

Before proceeding further I wish to submit a discussion of Mr. Bement's paper by F. S. Kedzie, Professor of Chemistry at the State Agricultural College, near Lansing. Professor Kedzie has analyzed numerous samples of Michigan coal and is well qualified to speak concerning this subject. His remarks follow:

"Your letter together with the advance copy of the paper on the testing of coal by Mr. Bement I have received. I agree with Mr. Bement in regard to the idea that all coal should be reported on the absolutely dry sample and the determination of moisture is without value except when carrying on coal in relation to the boiler test. I disagree with Mr. Bement in regard to the usefulness of the test for volatile matter as I believe that the volatile matter of coal can be very easily estimated and is a factor worth noticing. My reason for this is that if the coal contains a large amount of hydrogen and hence yields a large amount of volatile matter by the crucible test, we then know that the coal will be more or less difficult to fire properly by the ordinary fireman and that there will be much greater loss by unconsumed carbon in the smoke. Mr. Bement lays great stress on the determination of the ash and in order to determine this factor it is going to be necessary to burn the coal in the crucible. It is a very little additional work to burn it for seven minutes in the *closed crucible* and in this way determine the volatile carbon and I think it is well worthy of doing.

His remarks in regard to the value of the determination of sulfur I agree with in general, but I believe that the amount of sulfur is of sufficient importance to be worthy of attention and that in specifying the requirements for coal for even boiler consumption, I think that sulfur should be taken account of. I feel confident that any fireman will tell you that where the coal contains large quantities of sulfur the breeching is eaten away and the boiler more likely to damage than when a coal freer from sulfur is employed for fuel. I am rather surprised to note that Mr. Bement says that the coals from the Illinois basin run as high as they do, i. e., he says the minimum of 14,000 B. t. u. That seems to me a rather high minimum. I think this is all the remarks I have to offer you."

"Concerning the problem of moisture it is at least suggestive to note that from the results of the tests at the St. Louis plant that lignite and lignitic coals are apt to show a greater percentage of moisture in the car than in the mine sample; that bituminous coals containing over 5 per cent. moisture are apt to show less moisture in the car than in the mine sample; that bituminous and semi-bituminous coals containing less than 5 per cent. miosture generally show a gain of moisture in the car samples; that the general average of the sulphur in all analyses shows an increase in the car sample above that in the mine sample, due to a more rigid exclusion of impurities in sampling than in mining; and that the greatest difference between car and mine samples is in the percentage of ash, the car samples showing on the average a decided gain." "Economic Geologist," Vol. 1, No. 6, p. 593, 594.) It may be added, however, that there appear to be rather numerous factors which are to be taken into account in estimating the value of these deductions.

Mr. Campbell has deduced a new scheme of hydrogen-carbon

classification of coals which will probably have increased importance in analytical work. This scheme was found to fit in well with all the coals tested at the St. Louis plant. ("Economic Geologist," Vol. 1, No. 6, p. 595).

Whatever may be the outcome of Mr. Bement's proposed new scheme of commercial analytical work, it is at least worth while to notice that Mr. N. W. Lord, who is abundantly well qualified to do this work gave his results in ultimate and proximate analysis according to the prevailing fashion, calorific value was determined by the Mahler bomb calorimeter. It may be added here, however, that Mr. Bement's remarks concerning moisture are abundantly substantiated by Mr. Lord's work. It may be observed in a general way, at least with our Michigan coals, that the amount in excess of moisture lowers the number of B. t. u., even taking into account the personal factors of sampling and the variations of shipment, size, and usage of coal in the furnace.

Concerning some results of my Bay county work, Dulong's formula gives as good results as any in an ultimate analysis. In this computation we have:

B. t. u. equals (146 x per cent. carbon) plus [(620 x per cent. hydrogen minus ⅛ oxygen)] plus (40 x per cent. sulphur). In this equation the three factors are to be considered separately and then added; that is the amount of carbon is to be multiplied by 146 giving result one. From the amount of hydrogen must be subtracted the ⅛ of the percentage of oxygen and the result multiplied by 620 giving us result two. Finally the percentage or amount of sulphur multiplied by 40, gives us result three, which added to the two preceding results gives the equivalent in B. t. u.

Mr. Alfred C. Lane, State Geologist of Michigan has determined the following formula from what is known as a proximate analysis. B. t. u. equals (146.6 x per cent. combustible) plus (40 x per cent. sulphur). By the per cent. of combustible in the first equation is, of course, understood the amount of fixed carbon and volatile combustible matter.

I do not agree with Mr. Bement concerning the value of an iron-sulphur determination although it is well to take into account the difference in the value of coals from the Michgan and Illinois basins. Here in Michigan we have a coal running about 7 to 8 per cent. of sulphur which cannot be put on the market for fifty cents per ton. Another vein immediately above runs about 3 to 4 per cent. of iron-sulphide for which there is a ready market. Moreover I have numerous times been in a boiler room in a certain Chicago hotel where coal running high in iron and sulphur was the bane of the fireman's life; other Illinois coals used under approximately the same average conditions giving but very little trouble.

This brings me to the final paragraph of the value of chemical analysis in supplementing lithologic elements, dip, and elevation of coal beds, in determining the correlations of coal horizons. I

would also like to add a line concerning the recent classification of the coal-bearing Pennsylvanian formations in Volume II of Chamberlain's and Salisbury's "Geology," in which the Pottsville, the lowest coal-bearing formation, is separated from the coal measures of which it is considered a part by I. C. White and Stevenson, two of the best qualified observers to judge of its relationship. In Ohio some of the most productive beds are considered by Prosser as belonging to the Pottsville and our Michigan beds are in part correlated with them by David White. Such scholastic imaginings by partial parlor geologists are only confusing and detrimental to the development of the stratigraphy of the coal-bearing formation.

*Dr. Edward Gudeman*—Mr. Bement's suggestion that the determinations of ash, size and heating power of the pure (carbon contents) be the only considerations, meets with my approval, and will lead to the final result required, giving the steam producer what he has stipulated for and for what he is paying. All determinations must be made on or figured to actual dry coal, as the water contents is variable and air dried means absolutely nothing. The point that Mr. Bement does not bring out at all is how the heating power is to be determined, except so far as he states that the combination of various substances cannot be different under the boiler than in the calorimeter. The test would then be a calorimeter one and this used as indication of the heating power. I do not believe that the determination of heat units by means of the calorimeter indicates the practical efficiency of the fuel. I believe in the determination of the volatile matter and the fixed carbon and then using these figures for the calculation of the heating power of the pure coal. Fixed values even if arbitrary can be accepted for the value of the volatile matter and for the fixed carbon in terms of B. t. u's. A large series of tests have shown me that such calculated values are very close to practical efficiency obtained from the coal; that is comparison between results obtained as stated, calorimeter tests and actual evaporation tests show the calculated efficiency to be the nearest to actual efficiency. For comparison of different grades of coal such test has been found to give comparative results agreeing with actual results obtained.

I do not agree with Mr. Bement that the moisture test should be abandoned, except so far as all determinations to be made and results obtained should be stated as on dry coal. The moisture should be determined as a check on the amount of coal actually delivered. Specifications should state that coal should contain XXXX lbs. per ton of dry coal, and moisture test in connection with actual amount delivered should be a consideration, simply to enable the buyer to get the number of pounds called for. It is a determination to be taken into consideration with the quantity of coal. As an indication or even a consideration of quality, I agree with Mr. Bement that the determination should be omitted.

*Mr. W. J. Green*—(Cedar Rapids & Iowa City Ry. & Lt. Co.,

Cedar Rapids, Iowa.)—Mr. Bement's classification of the essential features governing tests for inspection service in the purchase of coal will, if applied, become an important factor in making such service more practical for general application. A large amount of uncertainty, which may cause confusion, disputes and possible litigation, is eliminated. The establishment, by an authoritative body created by act of Congress or state legislatures, of "authoritative values" for ash, moisture and the heating power of the pure coal of different sizes as mined, might still further simplify the proposition; and might make possible freight classifications based on the amount of ash and moisture, as well as on the size. The whole burden of high ash and moisture, as affecting price, would not then, necessarily, fall upon the purchasers of coal low in ash and moisture. Authoritative weights and weighing of the coal before it has been subjected to atmospheric conditions might also be advantageously established.

It seems reasonable to believe that "authoritative values" must first be predetermined and, possibly, continuously determined, before the purchase of coal under specifications stipulating its composition can become generally applicable—applicable to localities other than those forming a comparatively small area, in which an enormous tonnage can be supplied to many large consumers by resident operators under resident inspection service.

With the establishment of "authoritative values" and weights, the proposition of buying under specifications stipulating composition becomes greatly simplified. The purchaser may readily determine whether coal is being furnished from the district named in the contract. The specifying of the district or mine would, by reason of "authoritative values" for that district or mine, fix the composition of the coal to be furnished. The purchaser may make his own tests for ash, with an arrangement for disinterested inspection service if discrepancies are found, or may arrange for regular inspection service. I ask Mr. Bement whether discrepancies, except in moisture, between "authoritative values" of the coal as mined and values determined by proper sampling at delivery of coal in the boiler room, could occur other than by adulteration of the coal, either intentionally or through carelessness in loading; or does the heating power of the pure coal—at least from some districts—deteriorate sufficiently when exposed to the air, that the length of time between mining and delivery may cause an additional complication?

*Mr. F. S. Peabody*—Having no technical experience as an engineer, it is impossible for me to offer any discussion that would be worthy of presentation to your Society, but I do believe that uniformity of contract and specifications should be aimed at by all buyers and sellers of coal, and that as few technical, debatable questions should enter into that contract as possible; simplicity and uniformity to be the main features to be considered.

I have read Mr. Bement's paper with great interest and fully approve of the suggestions he makes. Years of experience as a seller of coal have put me against all sorts of theoretical but not practical specifications. Some of these specifications work out to the benefit of the seller, some of them to the buyer,—each party to the contract, however, always wishing to have the specifications drawn his way.

I believe that a simple and practical method of arriving at the actual value of coal has been outlined by Mr. Bement. I believe coal should be sold of a basis of so many B. t. u's. for a cent, and the sooner a uniform method of determining the actual value of coal and a uniform form of contract between buyer and seller that is recognized as fair to both, can be determined upon, the better it is will be for the commercial interests of the country.

*Mr. W. D. Richardson*—The only suggestion I would make in connection with Mr. Bement's paper is that a determination of moisture ought certainly to be included in every coal analysis. I had thought that this point was so universally acknowledged that no one could possibly take the position that it was not worth while to make the determination. I know of no product capable of absorbing moisture, in which the determination of the moisture is not advisable. In most products the determination is easily accomplished without great expenditure of time. So no objection against the making of it can be urged on the ground of laboratory practice. The very fact that moisture fluctuates to a large extent in coal is a most urgent reason for determining it. Again, in a boiler test it is absolutely necessary to know the moisture content of the coal in order to make the necessary calculations, and in daily practice it is important to know how much water goes into the furnace with the coal. In general I can see no valid reason why moisture should not be determined.

*E. A. Balsley*—(M. W. S. E.)—From the discussion this evening, it would seem that sulphur has no tendency to decrease the heating power of coal. In my experience in the use of coal in furnaces for the manufacture of forgings, I have found that where the heating power is low, the coal is invariably high in sulphur.

I have assumed that this characteristic was due to excessive sulphur, as tests did not reveal any elements that would have a tendency to reduce the heating power.

I would like to hear from some one as to whether my assumption was correct.

## CLOSURE.

*Mr. A. Bement*—It appears to be the general opinion that the recommendation is for the consideration of moisture values to be abandoned, or in other words, not taken into account. On this point I wish to remove any question regarding my position, as it would appear that I did not make myself sufficiently clear.

The fact must be kept in mind that no value of fuel as purchased can be established without taking moisture into consideration, because it is always present, and the operator must pay the miner for its weight the same as he pays for the coal associated with it. He must sell it and the consumer must buy it, whether they wish to do so or not. Therefore the fact that it must be recognized is apparent. And my suggestion is, not that it be eliminated, but that it have more exact consideration, and to this end, that representative moisture values be established, and that such factors shall be employed as constants in connection with other analytical values in calculating fuel values. The ash and heating power would be obtained by analysis, in connection with which the proper moisture value already established would be used. This scheme, however, can not at present be put into general practice, because moisture values have not been determined with sufficient accuracy. But if our Geological Survey will establish such values for Illinois, one of the difficult features of the fuel inspection service will be simplified.

The matter of "air-dried" moisture is one regarding which there is much confusion of opinion as to what is implied by the expression. Prof. Parr tells us that it is what may be termed an artificial condition produced in the laboratory to facilitate accurate weighing. This being the case, then such moisture figure should not be one of the exhibits of the report any more than the other weighings, etc. I also work with partially dried coal to facilitate accuracy, but always consider it as a condition of staple moisture, and not as any particularly characteristic degree of dryness, and the specific amount of drying is dependent on the degree of humidity and temperature of the laboratory, so the condition of partial dryness will necessarily vary according to conditions, and this is as it should be, because the moisture content of the sample should be staple to the particular moisture conditions at the time analysis is made. This quantity of moisture while being one item of the laboratory records is not reported, however, because it has no bearing on the quality of the coal, as it is never found in practice outside the laboratory.

Instead of there being a misconception on the part of engineers as to the chemist's position regarding moisture, it is in my opinion that it is rather the chemist's conception of the matter that is in question. This practice of basing values on the "air-dried" moisture, originated under the assumption that it was a characteristic quantity determining values in actual delivery to the customer. Its quantity, however, with bituminous coal is always lower than when the fuel is purchased or sold. It is certainly not to the advantage of the purchaser to be told that moisture is 6 to 8 per cent., when as a matter of fact he must buy 10 to 12; or with the operator when he must pay the miner for 12 to 14 per cent.

The discussion of Prof. Kent corroborates my contention that the air-dried moisture has been considered to have an actual bearing on fuel values, and the practice at the laboratory of the U. S.

Geological Survey at St. Louis, even goes further in attempting to fix this fictitious value, because the astonishing practice of adding the oxygen and hydrogen of the moisture remaining after air-drying to these elements in the coal, or in other words, considering water is coal, illustrates the matter very clearly. Further, a new air-drying scheme has been devised, using absolutely dry air at a fixed temperature, which will give quite a different result than the drying under atmospheric conditions, the one necessary for accurate laboratory work. And the reason for this new scheme is, that atmospheric conditions affect the result, showing that an actual quantitative value is ascribed to the "air-drying."

The State Geological Survey reports the moisture of an Illinois coal seam as follows:

Moisture lost on air drying........................4.14
Moisture at 105 degrees...........................8.82

As a matter of fact, the moisture is 12.96 per cent. and it is not reasonable to consider it at 8.82 per cent. because the object of inquiry is to determine what it is in the seam, and the operator must pay the miner for 12.96 per cent., and if the coal is sold at the mine, the customer must buy 12.96 per cent. moisture and not 8.82, and with Chicago delivery it would not be less that 10.00 per cent. as an average for mine run. Assuming it desirable to report the reduction of moisture with air drying, then the statement should have been:

Moisture .......................................12.96
Loss in air drying.............................. 4.14

In relation to the above, it is sometimes said that sufficient data is afforded so that a person seeking information may calculate the actual quantity for themselves, but work done with public funds is expected to be for the benefit of the people at large, who are neither chemists nor engineers to any considerable extent, and do not know how to make such calculations or realize that they should be made, especially that of separating the water from the coal in the ultimate analysis as reported from the St. Louis coal testing plant.

The B. t. u. of the pure coal is not a "constituent" but a measure of heat value based on the coal itself, rather than on any fuel composition containing coal; or in other words, it reduces values to a common denominator, and enables direct comparisons to be made, which is certainly correct and logical, and if there is any criticism due, it should have been explained and defined more fully. Certainly the principle involved is no different than when heat values are given in terms of either dry or moist coal.

My contention is, that the heating power of the coal of any seam or at least a general locality of such seam—a county, for example—may be considered a constant, which means, when calculated to a pure coal basis, that it always gives approximately the same figure, and the only significant criticism is by Dr. Noyes,

who calls attention to the fact that sulphur is a variable. Its influence, however, is so slight, as to have no serious effect. In the example cited by Prof. Parr, the screenings should show a higher heating power than clean coal if heat is derived from the ash, but as a matter of fact, if in practice this does occur, it is not indicated by the resulting heat derived as compared with the clean coal.

While Prof. Parr agrees to the desirability of some basis of comparison between coal, he does not favor heating power, and would use the inert volatile matter, or in other words, the water of combination, which consists of all of the oxygen of the pure coal in combination with sufficient of the hydrogen to reproduce $HO_2$, therefore non-heat producing, the remainder of the hydrogen being available for heat production. Thus the pure coal would be composed of inert volatile matter and a remainder, and this remainder would be considered as being combustible, although it also contains nitrogen which is a non-combustible. Therefore, the assumption is, that the composition of the combustible is a constant in heat value, and necessarily a constant for different seams and geological fields, because the only variable recognized is that of water of combination, which leads to no more exact conclusion than the employment of heating power, because as this inert volatile increases, heating power is reduced in proportion, so that approximately the same result would be arrived at by either method. As a matter of fact, however, the inert volatile basis embodies one feature of error not present in the heat basis; this is nitrogen, and it takes no account of difference in available hydrogen, while the heat method does; as to variation in sulphur it affects each. But if it be assumed that each method has equal advantage, then their relative feasibility may be considered.

The heat method derives its data from the analysis which must be done anyway, thus consisting of only a simple calculation. If the resulting heat is low, the purchaser of the coal is not interested in whether it is due to the presence of water of combination or something else, because heat is all he is buying. While on the other hand, the inert volatile basis requires an extra laboratory process more difficult than the calorimetric determination. For this purpose Prof. Parr has devised apparatus and method * the results with which are dependent upon the accuracy of volatilization, a matter which is seriously in question. While its accuracy is open to doubt, it is by all means the simplest scheme available, because, while an ultimate analysis gives data from which the water of combination may be accurately determined, such analysis is one of the most difficult and delicate of laboratory processes, requiring expensive apparatus and involving considerable time.

In this connection, it is interesting to note the difference in

*Bulletin University of Illinois, Vol. 1, No. 20, and Illinois Survey Bulletin No. 2.

value for water of combination between results secured by the Parr method and as calculated from ultimate analysis:

| | ILLINOIS Seam No. 6. | ILLINOIS Seam No. 7. |
|---|---|---|
| Geological Survey, St. Louis, Williamson County: | | |
| Average of two ultimate analyses.............. | | 10.01 |
| Parr, Williamson County: | | |
| Average of nine proximate analyses............ | | 15.61 |
| McClure and Barker, Sangamon and Christian Counties: | | |
| Ultimate analysis.............................. | 15.13 | |
| Parr, Sangamon and Macoupin counties: | | |
| Average of six proximate analyses............. | 18.37 | |

which shows that the ultimate, which is the more exact analysis, gives lower results by an average of 37 per cent.

In an endeavor to illustrate the relation between the heat basis

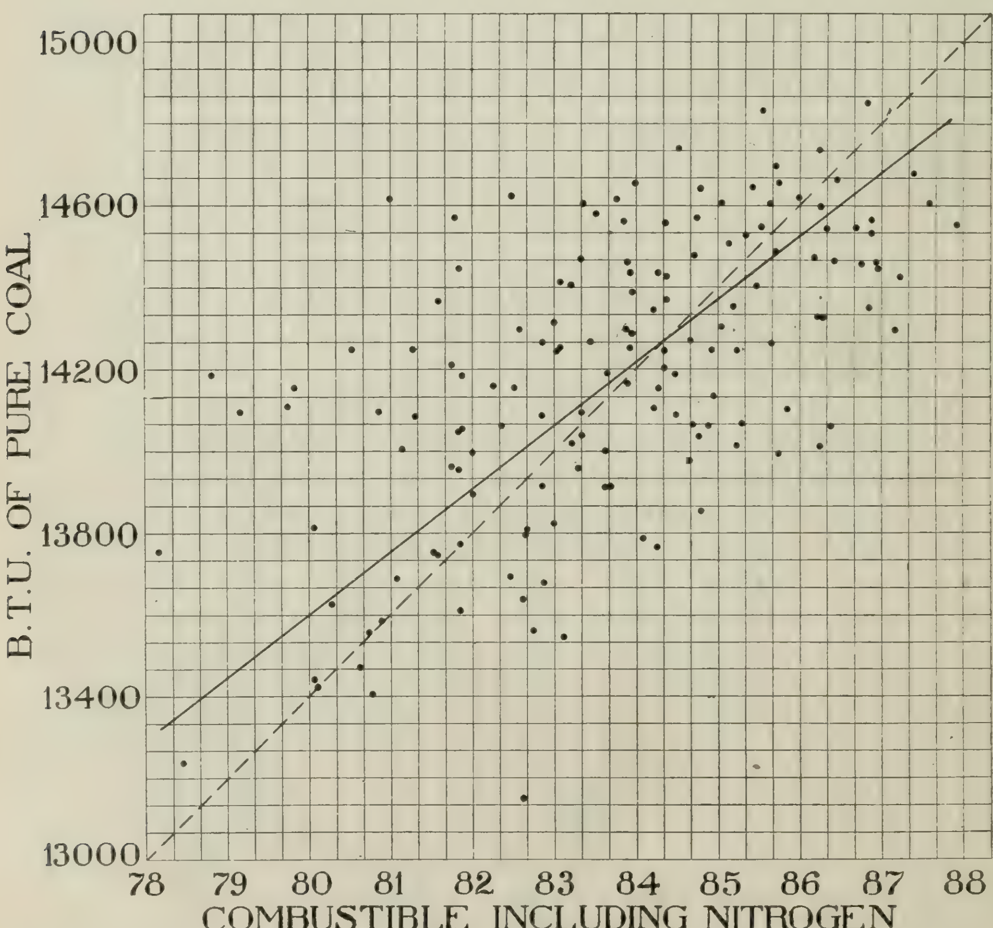



FIG. I. RELATION BETWEEN HEAT AND "COMBUSTIBLE" ILLINOIS COAL WITH PARR CALORIMETER.

*Bulletin University of Illinois, Vol. 1, No. 20, and Illinois Survey Bulletln No. 2.

[Substitute for top of page 785]

of comparison, and that of the water of combination, the 150 analyses on Illinois coal by Parr * were calculated to a pure coal basis and plotted in Fig. 1. Upon the assumption that the heat is in proportion to the quantity of the heat producing material, the broken line would show the relation as directly proportional. In these analyses, heating power was determined by the Parr calorimeter, and the "total combustible" by the volatile method before mentioned, to which the very scattered field of points is no doubt more particularly due. But the full line represents the apparent relation, which would indicate—if the values for "combustible" may be depended upon—that the less heat producing material, the more heat generated, which might be explained by the tendency of low-grade coal to be high in hydrogen; inasmuch, however, as such coal is also very high in oxygen, it would result in keeping down available hydrogen, so that such explanation is not acceptable, as illustrated for Illinois by taking the two most important seams, Nos. 6 and 7, as representing high and low quality, showing that available hydrogen in excess for No. 7 gives twice as much heat as is lost to No. 6, due to its greater sulphur. Thus it appears that instead of the inferior coal having superior combustible matter, it is in this respect inferior.

SEAM NO. 6.

| | Available Hydrogen | Carbon | Sulphur | Water of Combination | Nitrogen | Total Combustible | Total non-Combustible |
|---|---|---|---|---|---|---|---|
| McClure and Barker | 3.92 | 74.86 | 4.86 | 15.13 | 1.23 | 83.64 | 16.36 |
| SEAM NO. 7, WILLIAMSON COUNTY— | | | | | | | |
| U. S. Geol. Surv. St. Louis | 4.18 | 80.92 | 3.28 | 10.01 | 1.61 | 88.38 | 11.62 |

Having these facts in mind has assisted in understanding and realizing the tendency of the peroxide calorimeter to give results which are too low for good coal, and too high for poor coal. This calorimeter with the chlorate exciter has shown from 14,100 to 14,205 B. t. u. for pure coal from the No. 6 seam, which is mined so extensively in several counties south of Springfield, and from 14,205 to 14,400 for the No. 7 seam in Williamson County, which it too low for the No. 7 and too high for No. 6. I have taken the pure B. t. u. for Williamson County from the report of the U. S. Geological Survey as reported in professional paper No. 48, and have had Mr. C. H. McClure make determinations on a composite sample from a large number of borings in the No. 6 seam, with the following results:

| | Pure B. T. U. Mahler Calorimeter |
|---|---|
| Seam No. 7, average of 4 tests, U. S. Geological Survey.... | 14,624 |
| Seam No. 6, average of 5 tests, C. H. McClure............ | 13,918 |

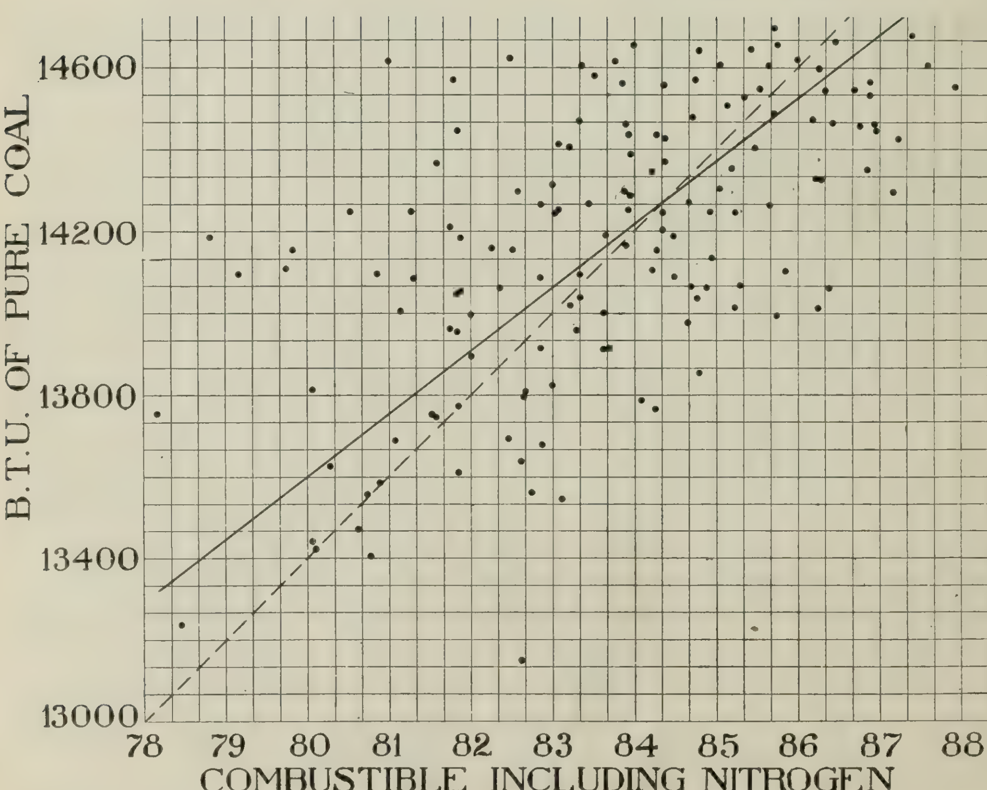



FIG. 1. RELATION BETWEEN HEAT AND "COMBUSTIBLE" ILLINOIS COAL WITH PARR CALORIMETER.

---

*Bulletin University of Illinois, Vol. 1, No. 20, and Illinois Survey Bulletln No. 2.

of comparison, and that of the water of combination, the 150 analyses on Illinois coal by Parr * were calculated to a pure coal basis and plotted in Fig. 1. Upon the assumption that the heat is in proportion to the quantity of the heat producing material, the broken line would show the relation as directly proportional. In these analyses, heating power was determined by the Parr calorimeter, and the "total combustible" by the volatile method before mentioned, to which the very scattered field of points is no doubt more particularly due. But the full line represents the apparent relation, which would indicate—if the values for "combustible" may be depended upon—that the less heat producing material, the more particularly due. But the full line represents the apparent of low-grade coal to be high in hydrogen; inasmuch, however, as such coal is also very high in oxygen, it would result in keeping down available hydrogen, so that such explanation is not acceptable, as illustrated for Illinois by taking the two most important seams, Nos. 6 and 7, as representing high and low quality, showing that available hydrogen in excess for No. 7 gives twice as much heat as is lost to No. 6, due to its greater sulphur. Thus it appears that instead of the inferior coal having superior combustible matter, it is in this respect inferior.

SEAM NO. 6.

| | Available Hydrogen | Carbon | Sulphur | Water of Combination | Nitrogen | Total Combustible | Total non-Combustible |
|---|---|---|---|---|---|---|---|
| McClure and Barker .... | 3.92 | 74.86 | 4.86 | 15.13 | 1.23 | 83.64 | 16.36 |
| SEAM NO. 7, WILLIAMSON COUNTY— | | | | | | | |
| U. S. Geol. Surv. St. Louis.... | 4.18 | 80.92 | 3.28 | 10.01 | 1.61 | 88.38 | 11.62 |

Having these facts in mind has assisted in understanding and realizing the tendency of the peroxide calorimeter to give results which are too low for good coal, and too high for poor coal. This calorimeter with the chlorate exciter has shown from 14,100 to 14,205 B. t. u. for pure coal from the No. 6 seam, which is mined so extensively in several counties south of Springfield, and from 14,205 to 14,400 for the No. 7 seam in Williamson County, which it too low for the No. 7 and too high for No. 6. I have taken the pure B. t. u. for Williamson County from the report of the U. S. Geological Survey as reported in professional paper No. 48, and have had Mr. C. H. McClure make determinations on a composite sample from a large number of borings in the No. 6 seam, with the following results:

| | Pure B. T. U. Mahler Calorimeter |
|---|---|
| Seam No. 7, average of 4 tests, U. S. Geological Survey.... | 14,624 |
| Seam No. 6, average of 5 tests, C. H. McClure............ | 13,918 |

To arrive at a conclusion regarding the accuracy of the Mahler calorimeter, I have taken all of the analyses from the U. S. Geological Survey, professional paper No. 48, which came within the limits of the diagram, together with Williams' analysis * of Michigan coal, and plotted them in Fig 2 on the same basis as Fig 1, from which it appears that the Mahler results can be considered as correct. The curve would no doubt be more properly located

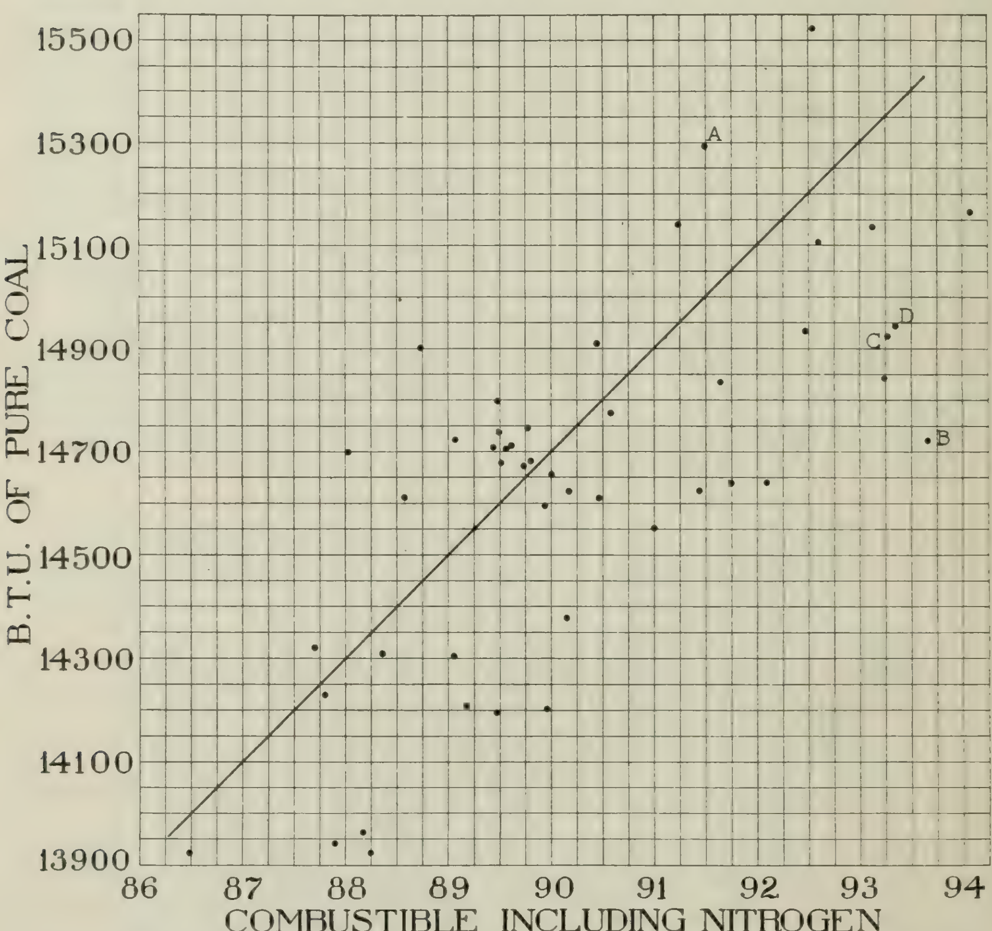



FIG. 2. RELATION BETWEEN HEAT AND "COMBUSTIBLE" MAHLER CALORIMETER.

a little lower down, but parallel to its present position, high sulphur coal having an influence on the location of some of the points; for example,—A contained about 1 per cent., C and D 5, and B about 9 per cent. The fact should be emphasized that the analyses shown in Fig. 2 are from several states and three different coal basins, while those in Fig. 1 are all of Illinois.

The Parr calorimeter, on account of its simplicity, low cost and accuracy of operation, is unique among physical instruments, and to it, more than anything else, is due the recent great advance in coal investigation, and there is nothing known that can take its

*Michigan Geological Survey, Vol. 8, p. 110.

place; the Mahler instrument is so expensive and difficult to operate that it can only find a very limited use, therefore it is most essential that means be devised to apply proper corrections to the indications of the Parr instrument. Mr. W. L. Abbott has suggested what appears to be the most feasible scheme, and I have

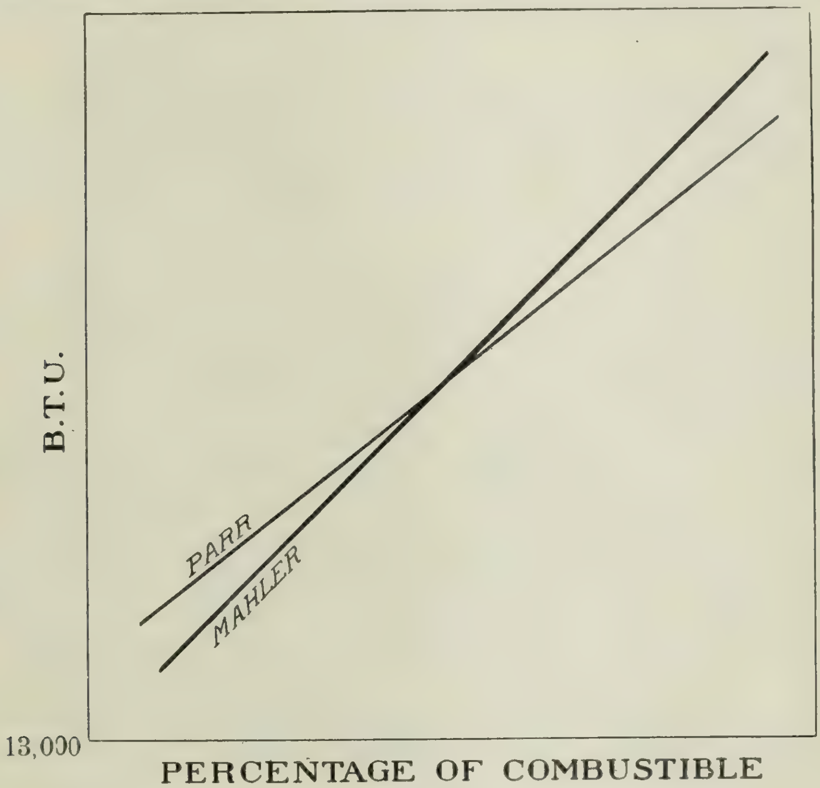



FIG. 3.

made Fig. 3 for purpose of illustration, wherein an assumed relation between the Parr and Mahler instruments is indicated. Thus if tests are run with both instruments on a variety of coal, the results on a pure B. t. u. basis may be plotted for each, from which corrections for the Parr instrument may be devised when the relative error has been determined, giving the same result as would be obtained had the Mahler calorimeter been used. For example, if there should be an agreement at 14,000 B. t. u., no correction need be applied, but below this the results of the Parr instrument would be reduced, or if above 14,000, would be increased an amount, which would produce an agreement with the Mahler instrument according to this standardization.

Correct B. t. u. determination is important to the coal purchaser, that he may get the heat he pays for, and to the dealer, that he may receive full payment for what he sells.

The most essential things required by the people at large, are correct moisture, ash and heating values, and a correct means of heat measurement. The accumulation of such values is, however,

no simple matter, and it is important that every scientist in public service realize this, plan for the execution of the work, and lastly, but most important, that the people provide the money for properly carrying it on. The right beginning has been made in Illinois in sampling seams, showing the coal is it lies in the ground, which is, however, quite a different thing from the fuel shipped from these seams.

The proposition to devise various features of furnace design suited to coal of different characteristics as to volatile content, is neither feasible nor desirable, because we now have too much confusion in furnace design. What is needed is a single standard design or type, that will be comprehensive enough to burn all kinds of coal.

There are some features of the discussion not referred to in the foregoing, therefore, I have made the following replies which are preceded by the name of the speaker or contributor:

Prof. Breckenridge suggests a different title to the paper, and in so doing makes a good point. His version would be more acceptable, however, if it were "Tests of the Characteristic Properties of Coal of Importance to the Consumer," because the object of the paper was to discuss the fuel testing business. I very much appreciate his endorsement of the term Pure Coal. So far as I know, the expresion is not original with me, and while I have elsewhere* explained my reasons for advocating its use, the expression "coal free from ash and moisture" would be more definite and exact, but it is cumbersome and unwieldy. However, things are what we call them, and I observe that the expression is coming more generally into use.

My statements regarding the coal tests made by the Geological Survey at St. Louis, referred only to the burning of coal under boilers, and this is, properly speaking, the only testing of coal that has been done at this plant. For example, if briquettes were made and burned, then it is a test of briquettes; likewise, experiments with coke ovens are coking tests; or if with a gas producer they are gas producer tests. The chemical work of the laboratory is and should be known as analysis of coal, because the accepted meaning of the word test implies comparison to some known standard, while that of analysis signifies discovery and original inquiry, therefore my remarks had no reference to any of the other departments mentioned.

Mr. Rice refers to variation in results obtained in volatilization by different chemists. These discrepancies are to be expected on account of the inexactness of even the best methods, and it is impossible for results to be duplicated by different chemists. Personally, I do not think it safe to attempt to make use of results

*Journal Americau Chemical Society, Vol 28 p. 632.

from volatilization in any exact sense, and have practically abandoned the determination of fixed carbon and volatile matter in nearly all cases.

In reference to the very fine coal or "duff" being of small value, I will say that reference was made to fine dust, or small coal containing the full amount of that size, which, for example, will pass through 100-mesh screen. The washed coal to which Mr. Rice refers through a ¼-in. diameter screen, I will say is far from being "duff," as it is one of the highest types of fuel made in this state, commonly known as No. 5 washed coal, and aside from the removal of a considerable quantity of the ash which enters the jigs with it, most of the very fine dust is also washed out, resulting in a greatly improved product.

Referring to the matter of sampling and basing judgment upon the character of the ash of a given field, this was not the idea of the paper. My arguments concerning ash referred to the determination of its quantity rather than characteristics, although the matter of the ash characteristic is one which could be profitably studied, and there is nothing in the paper suggesting the dropping of figures for ash from the exhibit of the analysis, because it is the most essential item.

I have and do advocate a very thorough analytical study of the characteristics of coal, but I think such studies should be confined to the coal itself, and not expressed in terms of the fuel. My paper concerned itself only with tests necessary for fuel coal in inspection service.

Mr. McArdle's experience with tests under boilers in the water works plants are, no doubt, useful to the city within certain limits, but not sufficiently exact to fix the heat value of coal between buyer and seller.

In reference to the influence of the quantity of ash on the heating power of the pure coal, Mr. McArdle reverses the proposition, because the effect of the presence of a high percentage of ash is not to increase the heating power of the pure coal, but to reduce the B. t. u. of the dry or moist fuel composition. Should two samples of dry coal show the same B. t. u., and one contain more ash than the other, the one with the most ash will necessarily have a high B. t. u. of the pure coal, not due, however, to the presence of this larger amount of ash, but to the fact that the sample containing it also contained coal of superior quality; calculation of a few samples will show this to be true.

With chain grate stokers, the range of desirability in size is much less than in general practice where a variety of furnace appartus enters into consideration. Some remarks which I have made in reply to Mr. Cheney's inquiries will illustrate this point.

Mr. Cheney states that it is evident that my paper was written in the interest of the coal producer or dealer, and I am very glad to have him say so if he thinks such was the object, because it

enables me to definitely state my attitude, which is one of absolute fairness. The suggestion has been made in the interest of the coal seller, purchaser and inspector, and I do not propose to favor any of my clients among these three classes of people. As a matter of fact, it was to Mr. Cheney that I first broached this matter of regulating the consideration of moisture. There would be more reason to consider my position as favoring the purchaser, because my clientage among purchasers is very much greater than among sellers or producers of coal. From the standpoint of the purchaser, it would be to his advantage, of course, for moisture values to be overestimated, but if the purchaser is unjustly favored, the dealers may find it out, and this will result to the discredit of the inspection service, therefore, for the benefit of everybody concerned, it is desirable to have the matter placed upon an equitable basis. The fact should be kept in mind that the object of the inspection service is to insure that the dealer renders the best service in his power, and when all of the factors under his control are analyzed, it appears that size of the fuel, amount of ash which it contains and the locality and seam from which it comes are the only things for which he can be responsible, therefore the variation in moisture due to condition of weather and temperature, are things over which he has no control whatever, and there is no more reason why he should be expected to take chances with such variable than the purchaser, therefore, on account of the impossibility of correctly determining moisture by analysis in regular inspection service, I suppose that a just and equitable moisture value be established by proper and independent investigation, and that such value when established be used as applying to the coal being tested. Thus, for a contract running a year, covering coal for some particular locality, the average moisture value for the point of delivery would be used in the calculation, the inspection service determining quantity of ash, size of the coal and heating power only.

As before mentioned, I had no intention of presenting an argument in favor of the coal dealer, but in view of the fact that Mr. Cheney gives me credit for so doing, I will say here, that the tendency of the inspection service is to require from the dealer, selected fuel, or in other words, the best of his product, and to pay him the price which should properly apply to the average product. Therefore, in full justice, a higher price should be received for the best quality, and instead of the attempt being made to base the specification on the best of the fuel, it should be applied to the average.

Referring to Mr. Cheney's inquiry regarding my reference to the value of the size of fuel, I will endeavor to make the matter clear. Different service requires fuel of different size; for example, locomotives must use egg size and cannot employ smaller coal to advantage, and locomotive fuel requirements are the most extensive single use for which coal is employed, therefore size has a

value independent of heating power. A locomotive could not use screenings irrespective of price, because it is fuel of large pieces rather than small, that makes it valuable to a locomotive, and this holds good through all classes of service, consequently the larger the pieces of coal, the more valuable they are in steam production as a general commercial proposition, which, of course, does not necessarily mean that a downtown office building can make steam with less money from egg coal than it could with No. 5 washed. Therefore, as before stated, size of the pieces has a value independent of the quantity of heat, so that even should the heating value per pound be constant through the whole range of size, the larger pieces are of increased value, because necessary in some particular service.

Dr. Noyes refers to Dr. Dudley's experience regarding the significance of the volatile matter determination in the selection of railroad coal. It is, of course, true, that fuel having a medium amount of "volatile" matter is best suited, but this is not necessarily an argument in favor of the retention of the volatile determination, because one may readily realize that neither lignite nor anthracite coal would be desirable for locomotive use, provided bituminous coal could be obtained, therefore one could make selection from mere inspection.

There seems to be a misunderstanding regarding what I mean by the expression pure coal, and it would appear that Dr. Noyes takes it as the equivalent of combustible, therefore I will say that it is what is covered by the expression "ash and moisture free;" in other words, all of the combustible having associated with it the two non-combustibles, water of combination and nitrogen.

Prof. Kent makes comparisons between certain coal on the assumption of moisture being excluded from consideration, which, of course, does not apply. The error is more mine than his, however.

He offers standards for valuation which are not as good as those of the Fuel Engineering Co., now so extensively employed, but which are not themselves established upon a proper basis. A comprehensive basis will require considerable original research to determine such features as the effect of presence of ash, etc.

Dr. Guderman agrees with me on all points with the exception of moisture, and my remarks elsewhere in this connection, will show that my suggestion did not imply the abandonment of the consideration of moisture.

Mr. Greene refers to deterioration of coal due to exposure to air, etc., between the time of production and delivery. I will say that it is no doubt true that some change takes places, but it is so slight as to be undiscoverable in this connection, except that for the locality in question moisture becomes less, thus the fuel really becomes better.

There could be no disagreement between actual and "authori-

tative" value so far as either ash or moisture is concerned, provided the authoritative ones were real and not fictitious, and in this connection Mr. Greene calls attention to a very important matter, which is, that the results of coal analyses which have so far been published, are, as a general thing, entirely worthless, because the sampling upon which the analyses have been made has not represented the actual fuel. To the uninitiated, the disposition is to consult some text book and read an analysis therefrom, purporting to represent the fuel subject to inquiry, and to base conclusions thereon. Whether or not this is a safe thing to do, some Chicago coal dealers have probably learned recently, as have many purchasers in the past. So far as I am aware, there has been nothing of any consequence published in the way of coal analyses, which can be considered as having an authoritative value; even of the sampling and analyses were properly conducted, it has not been so stated, therefore for this reason, one is unable to discover whether or not the work was correctly done, and one of the principal objects of my paper is to insist upon the necessity for proper values for the essential constituents of fuel.

Mr. Booth presents the question whether it pays mine operators to produce coal high in ash, which implies adulterations, or in other words, selling dirt as coal. I will say that it does not, because the miners charge more for mining rock than for coal. Notwithstanding the fact that the operator must assume responsibility for the dirt in the coal, his control over the miners is not always sufficient to compel them to properly clean it. The result is that whatever amount of dirt there may be in the coal, is what is convenient for the men to load and send out. Nearly all operators endeavor to produce cleaner coal than they actually do.

In reference to the ash item appearing twice on the wrong side of the ledger, it really occurs three times: first, because of its lack of fuel value; second, owing to the expense for its removal, and third, that its presence in the fire results in a poorer combustion, and therefore a lower heat efficiency, or in other words, interferes with the full development of the heat present.

Regarding the retention of volatilization in coal inspection service, Mr. Booth probably refers in his remarks to eastern conditions, where it would be more feasible to deliver a considerable variety of coal than the locality in question. Even under such conditions, however, one may detect the fuel by mere inspection. For example, if specifications call for semi-bituminous and bituminous was delivered, one could readily discover the fact without chemical test, or if need be, by the B. t. u. value of the pure coal.

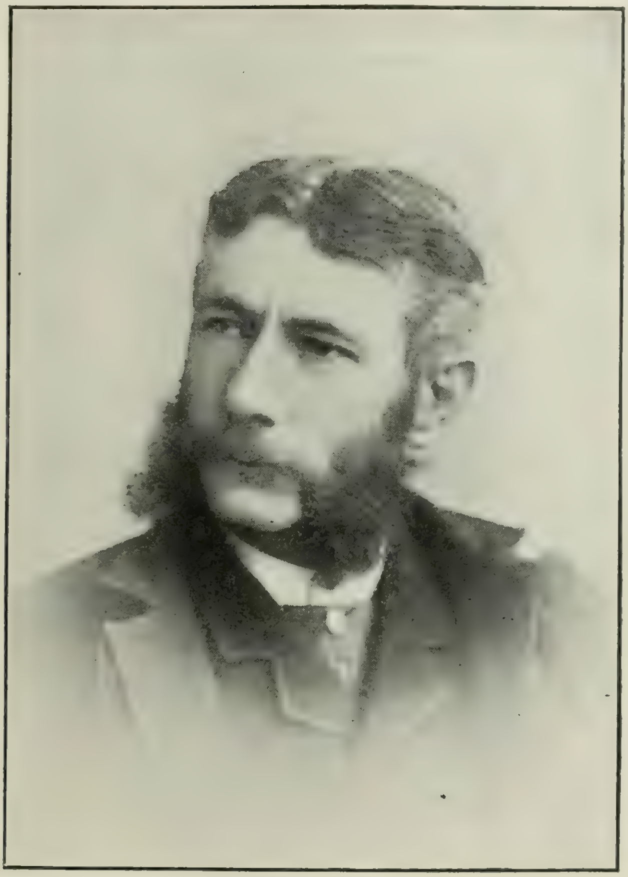
Mr. Balsley makes inquiry concerning sulphur, and I will say that its presence does decrease the heating power of the coal, and it is also true as a general proposition, that the poorer coals are higher in sulphur than are the better grades.

# IN MEMORIAM.

## JOHN SALTAR, JR.

John Saltar, Jr., son of John and Eleanor Gilmore Saltar, was born in La Harpe, Hancock County, Illinois, August 20, 1845. He was of old Pennsylvania Quaker stock and was the fifth John Saltar in direct descent.

He attended boarding school at Burlington College, Burlington, N. J., and while there, in 1863, he enlisted in the army for service in Pennsylvania. After three months he was mustered out, but the



patriotic feeling which led the boy of eighteen to enlist continued throughout his life; intense devotion to his country was always a marked characteristic of the man.

In January, 1864, he entered the Rensselaer Polytechnic Institute at Troy, and was graduated from it in June, 1867, with the degree of C. E. His first engineering service was with the Rensselaer & Saratoga (now Delaware & Hudson) R. R., with which road he remained until 1871, when he received an appointment from the Government of Ecuador which took him to Quito, where he remained until 1874. On his return to the United States, he accepted

a position as designing engineer with the H. B. Smith Manufacturing Company, of Smithville, N. J., and continued at this work until 1879, when he went with Witherow & Gordon, Engineers, of Pittsburg. His work with this company brought him to South Chicago in 1880 to superintend work which they were putting in for what is now the Illinois Steel Company. After the completion of this work he was employed by the New York, Chicago & St. Louis R. R. as assistant engineer of the Western Division. When the "Nickle Plate" was completed in 1883, he was appointed western manager of the Otto Gas Engine Works with headquarters in Chicago. In 1898 he went to Philadedphia as vice-president and chief engineer of this company and the following year he was elected its president, in which position he continued until his death.

It is said by those familiar with Mr. Saltar's work, that he did more for the development of the gas engine to make it a commercial success than any man since the time of Dr. Otto. The Holland submarine boat, the first successful boat of its class, was made possible by the gas engine designed by him. Boats of this type are now in use by the navies of the United States, England, Germany, Russia and Japan.

Mr. Saltar was an active member of the W. S. E. for twenty-two years.

He married Sally Coleman, daughter of Dr. J. P. Coleman, of Pemberton, N. J., September 15, 1870. She died December 4, 1871, leaving one son, Joseph C. Saltar, now living in Riverton, N. J. On June 8th, 1886, he married Mary Eleanor, daughter of Thomas W. Carrico, of Rockford, Ill. She died in Denver, Colo., in 1890. Two daughters, Mary and Margaret, now living in Rockford, were born of this union.

Mr. Saltar died at Concordville, near Philadelphia, Pa., July 12, 1906.

He was a firm friend and a good hater; he loved the truth and scorned even the appearance of deceit; he was in every sense—a gentleman.

AMBROSE V. POWELL,
THEODORE W. SNOW,
BERTRAND E. GRANT,
*Committee.*

## BENEATH THE CITY OF CHICAGO

Referring to the valuable paper by Mr. J. M. Ewen, "FOUNDATIONS IN CHICAGO," published in the JOURNAL for December, 1905 (vol. x, page 687) when the foundations were put down for the office building of the C. & N. W. R'y Co., Jackson Blvd. & Franklin St., the engineers, the Messrs. Shankland, kept a careful record of the material encountered in sinking the shafts for the caison foundations.

An artesian well was also sunk for a water supply to a depth of over 1,400 ft. below the street level. A careful record was also kept of the material encountered in this bore-hole which, by the way, was started at 10 inches diameter and was gradually reduced to 5 inches diameter at the bottom.

The engineers prepared a sketch showing the disposition, thickness and character of the several strata of the caison well and of the bore-hole. This sketch has been reproduced and is presented herewith.

Other interesting data on this subject can be found in the Engineering World, July 27th, 1906, wherein is shown the records of borings at State and Washington Sts., Monroe and Dearborn Sts., and at the Sears, Roebuck & Co.'s new plant at Kedzie and Harvard.

A letter from the Messrs. Shankland is here presented: W.

JUNE 4TH, 1906.

*Mr. John H. Warder, Sec'y Western Society of Engineers, Monadnock Building, Chicago.*

DEAR SIR—The following is a description of artesian well boring:

The cut shows an artesian well boring made at the Chicago and North Western Railroad office building, Jackson Boulevard, Franklin and Quincy Sts. It shows the rock underlying the clay to be solid rock from its surface about 86 feet below the datum, or about 100 feet below street level to the bottom of the boring.

As the cut shows the rock is mostly limestone, only one stratum of sandstone being found and a thin layer of what the driller described as a caving rock which was difficult to go through. When the lower stratum of white sand stone was struck water rose in the tube to within 100 feet of the surface.

Many of these artesian wells have been bored in difficult parts of Chicago, and all show rock as far as the borings extend.

In a boring made at the Masonic Temple when that building was erected, the driller reported having gone through about

# C. & N. W. R'y Office Building.

## Record of Caisson No. 39.

| | |
|---|---|
| + 5.25 | Basement Level |
| | Soft Yellow Clay |
| ± 0.0 | |
| | Hard Blue Clay |
| − 7.0 | |
| | Sticky Blue Clay<br>Becomes appreciably softer from −7′ to −12′ where it is very soft and continues so to −30′. From −30′ it becomes gradually stiffer to −40′, where consistency is about same as at ± 0. Continues to harden to −44′ where it must be grubbed. |
| − 50.0 | |
| | Hard Pan<br>Must be grubbed.<br>Numerous sand pockets from −58′. |
| − 62.0 | |
| | Slippery Blue Clay<br>Digs out with shovels. |
| − 69.0 | |
| | Hard Pan<br>Must be grubbed.<br>Considerable sand from −75.5′ |
| − 77.0 | |
| | Fine, dry, white sand (soft)<br>Stands up well. |
| − 85.0 | |
| | Sand and Stones. |
| − 85.75 | |
| | Bed Rock (Limestone) |

## Record of Artesian Well.

| | |
|---|---|
| + 5.66 | Initial Elevation |
| − 86.0 | |
| | Lime Stone |
| − 422.0 | |
| | Blue Shale |
| − 575.0 | |
| | Lime Stone |
| − 928.0 | |
| | White Sand Stone (soft) |
| − 1084.0 | |
| | Dark Caving Rock |
| − 1101.0 | |
| | Lime Stone |
| − 1391.0 | |
| | White Sand Stone<br>Water found at surface of sand stone. Water stands 100 feet from surface |

250 feet of white marble. It is, however, the clay above the rock that is the most interesting geologically.

Gold bearing quartz is found, assaying over $7.00 per ton.

Boulders are found lying in the stratum of sand and muck right on top of the rock. These boulders contain quartz, crystals, iron pyrites, etc.

The most remarkable find was made however, in one of the caissons for the foundation of the addition to the Fisher building now being erected. It was a large boulder containing quartz studded with brown crystals. These brown crystals when pulverized and heated in a crucible and taken into a dark room had a bright steady glow, like radium, and gave off the very rare element helium found in the northern light and the sun's corona. Unfortunately this boulder, weighing 5 or 6 tons was sent out and dumped into the lake before its remarkable qualities were discovered and only a few small pieces were preserved.

Yours truly,
(signed) E. C. SHANKLAND.

---

## WATERWAYS FOR BRIDGES AND CULVERTS

In the April issue of the Journal there was published a valuable paper on the above subject, Volume XI, page 137. In that paper, in the discussion offered by Mr. Dun there was introduced matter from advance sheets of water supply and irrigation paper No. 147, written by Mr. E. C. Murphy, who has since then sent in a further contribution to the discussion of this subject, which is herewith presented to the readers of the "Journal."

Washington, D. C., June 13, 1906.

Editor "Journal Western Society of Engineers,"
Monadnock Building, Chicago, Ill.

Dear Sir:—I find on my table, on my return to Washington, D. C., from a few months' trip, a copy of No. 2, vol. II., "Journal of the Western Society of Engineers," which contains a paper on "Waterway for Culverts and Bridges," by G. H. Bremner and others.

I am pleased to see the quotation from Water Supply Paper No. 147, "Destructive Floods in the United States in 1904." If there is yet opportunity for discussion of this paper, I would like to make some comments on the formula, page 155. (p. 190, W. S. P. 147).

1. It gives the rate of run-off from drainage areas, and not the area of the water-way.

2. It is based on measurement of discharge of natural channels; measurements of flow through artificial channels, such as pipes and culverts, are not included.

3. It is proposed for the northeastern part of the country only, because for this section of the country only are there a sufficiently

large amount of data of flood-flow to warrant the making of the formula.

4. It is only a tentative formula, because the period of observation has not been sufficiently long to include the largest floods that will probably occur in this section.

5. It is not applicable to small drainage areas, because the data on which it is based contains measurements from only five drainage areas of less than five square miles.

After the maximum run-off is obtained, the velocity of the stream, at the point where the structure is to be built, must be determined. If free, unobstructed flow is to be premitted, the velocity will depend mainly on surface slope, hydraulic radius and roughness of channel. If obstruction of flow is permissible, the velocity will depend to a considerable extent on the height to which the water may be allowed to rise in front of the structure. The method suggested on pp. 190-193 W. S. P., 147, for finding the water-way area, is for a case of unobstructed flow in natural channels, and is only applicable to the larger structures, as bridges and arched culverts. Mr. Dun's imperical formula is undoubtedly better than the one that I have suggested for the design of small, artificial waterways.

The Hydrographic Branch of the U. S. Geological Survey is extending its work to the smaller streams as rapidly as the funds at its disposal will permit, and it is hoped that in the near future data will be available for the preparation of a formula for small streams, as well as for the larger ones.

Very truly yours,

(Signed) E. C. MURPHY,
*Engineer.*

## SOCIETY NOTES.

### *MINUTES OF REGULAR MEETING, October 3, 1906.*

A regular meeting of the Society (No. 582) was held in the Society rooms Wednesday, October 3, 1906.

The meeting was called to order about 8.20 p. m. with Vice-President Abbott in the chair and about fifty members and guests present.

The Secretary read the minutes of the meetings held September 5 and September 19, which were approved, and reported from the Board of Direction the election into the Society of the following:

Otto Gersbach, transferred from........................Junior to Active
Herbert M. Wheeler, Chicago, transferred from........Junior to Associate
Edward C. Stone, Chicago....................................Active
Charles Elliott Henderson, Parsons, Kas........................Junior
Wm. D. Richardson, Marysville, Kas...............................Active
Henry F. Treadway, Chicago.................................Associate
Carlos A. Wiener, Chicago.......................................Junior
John C. Penn, Chicago...........................................Junior
Allan F. Owen, Chicago..........................................Active
Arthur C. Smith, Chicago........................................Active
Vernon C. Ward, Chicago.........................................Junior

Also that the following applications for membership had been received.

Harry J. Ott, Chicago...........................................Junior
Raymond G. Lawry, Chicago......................................Active
Edward M. Miller, transfer from Junior grade.
Harry D. Cromwell, McCoy, Col...................................Junior
Frederick L. Jefferies, Chicago.................................Active
L. E. Gould, Chicago............................................Active
Chas. A. Smith, Chicago.........................................Active
Myron B. Reynolds, Chicago......................................Junior
E. Robins Morgan, Chicago.......................................Active
Eugene F. Hiller, Chicago.......................................Junior
Hervey B. Hicks, Chicago........................................Active
Frederick H. Avery, Chicago.....................................Active
John C. Sanderson, Evanston.....................................Active

The Secretary called to the attention of the Society the fact that there had been, until recently, for a period of nearly two years a committee, of which Mr. John Ericson was chairman, to report on the establishment of a mural standard of lengths; that several meetings of this committee had been held, and efforts made to secure a suitable position for such a standard of lengths 100 feet long, for the use of engineers and surveyors, but thus far without success. Also that, at the regular meeting of the Society of June 6, a letter from Mr. Ericson had been read, in which he asked that his committee be discharged, as they had not been able to accomplish the work for which they had been appointed.

Mr. Andrews Allen offered a resolution that a new committee be appointed to further consider the question of establishing, in the city of Chicago, a standard of lengths along the lines of the work proposed for the committee which had been recently discharged. The motion was carried, and the appointment of this committee was left in the hands of the president.

The chairman announced that the replies by postal cards to the circular sent out regarding the increase of fees and dues, thus far received, indicate that the idea is generally favored.

There being no more business to bring before the Society, Mr. A. Bement, M. W. S. E., was introduced, who read his paper on "The Testing of Coal." Communications bearing on the subject were presented by the secretary from Dr. W. A. Noyes, Prof. William Kent, of Syracuse, N. Y., Dr.

Edward Gudeman, of Chicago, Mr. W. F. Cooper, of the Geological Survey of Michigan, Mr. F. S. Peabody, of Chicago, Mr. W. J. Green, of Cedar Rapids, Iowa, Mr. W. M. Booth, of Syracuse, N. Y., and Mr. W. D. Richardson. of Chicago.

Oral discussion then followed from Prof. S. W. Parr, Prof. L. P. Breckenridge, Dr. H. F. Bain and Messrs. Geo. S. Rice, E. H. Lee, E. H. Cheney, P. C. McArdle and E. A. Balsley, with closure by Mr. Bement.

The meeting adjourned at 10:45 p. m.

## *MINUTES OF EXTRA MEETING, October 12, 1906.*

A special-extra meeting of the Society (No. 583) was held in the Society rooms Friday, October 12, 1906. The meeting was called to order at about 8:20 p. m., with President Arnold in the chair and about seventy-five members and guests present.

There was no business brought before the Society, but Mr. L. E. Cooley was introduced, who opened the discussion of the subject, "Public Policy Demands a Waterway System." He was followed by Mr. Chas. T. Harvey, who built the first canal and lock at the "Soo" in 1853-5. The Hon. Joseph E. Ransdell, M. C. of Louisiana, chairman of the National Association for Promoting a Waterway System, was then introduced, who made a strong plea for public sentiment to favor waterways. Mr. Isham Randolph, M. W. S. E., followed Mr. Ransdell with a few words, and was succeeded by Mr. John A. Fox, of the National Rivers and Harbors Congress. Mr. Thomas Dowse, for many years interested in the matter of waterways, also spoke on the subject.

The meeting adjourned about 10:45 p. m.

## *MINUTES OF THE EXTRA MEETING, October 17, 1906.*

An extra meeting of the Society (No. 584) was held in the Society rooms, Wednesday evening, October 17, 1906. The meeting was called to order at 8:25 p. m., with Vice-President Abbott in the chair, and with about seventy-five members and guests present. As there was no business to be considered by the meeting, Mr. Bement was introduced who read his paper, "The Suppression of Industrial Smoke with Particular Reference to Steam Boilers."

Discussion followed from: Mr. Robt. H. Kuss, M. E., for the City Club; Mr. Carl Scholz, of the Consolidated Indiana Coal Co.; Mr. Frank Elliott, chief engineer of the Northwestern Elevated Railway power plant; Mr. W. L. Goddard of the International Harvester Co.; Mr. Henry Kreisinger of the U. S. Geologicay Survey Fuel Testing Plant, at St. Louis; Mr. A. J. Saxe, chief engineer of the Railway Exchange building; Mr. E. A. Taylor, of the Fuel Engineering Co.; Mr. Edwin Fitts, of the Murphy Iron works, Detroit; Mr. Joseph Harrington, of the Green Engineering Co.; Mr. O. U. Bean, of the U. S. Smokeless Furnace Co.; and Mr. John C. Schubert, City Smoke Inspector, with a brief closure from the author.

Communications were received from: Prof. Wm. Kent. of Syracuse, N. Y.; Mr. J. J. Merrill, of Chicago; The Murphy Iron Works of Detroit, (Chicago office); Mr. F. S. Peabody, Chicago; Mr. H. W. Woodward, Assistant Supervising Engineer. Cleveland, Ohio; Mr. E. B. Powell of the New York Edison Co.; Mr. G. S. Bergendahl, W. M. S. E., Koken Iron Works, St. Louis; Mr. Clinton Rogers, Rochester, N. Y.; Mr. W. J. Green, Cedar Rapids, Iowa; Mr. Frank H. Pond, of the American Stoker Co., Chicago; Mr. H. L. Van Zile, of the Franklin Boiler Works New York; Mr. J. L. White, Milwaukee, Wis.; Dr. R. S. Moss, M. W. S. E., from Rochester, N. Y.; and Mr. E. H. Hovey of the Hydro-Carbon Furnace Co., Chicago.; but these were read by author's name only, for lack of time, as the hour was late.

Meeting adjourned at 10:30 p. m.

## *MINUTES OF THE ELECTRICAL SECTION.*

A regular meeting of the Electrical Section, W. S. E. (the 18th) being an extra meeting of the Society (No. 585) was held in the society rooms Friday evening, Oct. 19, 1906, with about eighty-five members and guests present. The meeting was called to order about 8:15 p. m. by Mr. George A. Damon of the Executive Committee, who called on Prof. P. B. Woodworth for a few remarks "for the good of the Section." Messrs. Scheible and Almert followed Prof. Woodworth with suggestions of what might be done to create greater fellowship and sociability among the members. A motion was offered by Mr. Scheible, seconded and carried, that a committee be appointed to devise ways and means to promote and extend sociability and fellow interest among the members, and at the meetings. There was some talk on the subject of a program for the meetings, and the announcement was made that the next meeting of the Section would be held November 16, 1906, when Mr. Schwab, of Adams & Schwab, would present an address on the Sears-Roebuck company's new plant.

Mr. Damon asked Vice-President Abbott to preside during the rest of the meeting. Mr. Abbott introduced Mr. P. Junkersfeld, who gave an illustrated talk on "Electrical Power Systems in Some European Cities." This included views pertaining to some of the electrical power stations in London, Berlin, Paris, Belfast and Glasgow.

The meeting adjourned at 10.15 p. m.

## *MINUTES OF REGULAR MEETING, November 7, 1906.*

A regular meeting of the Society (No. 586) was held in the Society rooms Wednesday, November 7, 1906.

The meeting was called to order about 8:15 p. m. with President Arnold in the chair and about thirty members and guests in attendance.

The usual order of business was not followed, but Mr. Charles Hudson was introduced who presented the paper written by his father, Mr. Chas. H. Hudson, M. W. S. E.,—"Notes on Road Resistance," which paper had been printed and sent out in advance.

Discussion followed from President Arnold and Messrs. Bley, Abbott, Warder and Seely, with closure by Mr. Hudson.

After the presentation of the paper of the evening it having been determined that a quorum of members was present, the minutes of previous meetings (October 3, 12 and 17) were read and approved. The Board of Direction reported that the following had been elected into membership:

| | |
|---|---|
| Harry J. Ott, Chicago | Junior |
| Raymond G. Lawry, Chicago | Active |
| Harry D. Cromwell, McCoy, Col | Junior |
| Frederick L. Jefferies, Chicago | Active |
| Lawrence E. Gould, Chicago | Active |
| Chas. A. Smith, Chicago | Active |
| Myron B. Reynolds, Chicago | Junior |
| Elias R. Morgan, Chicago | Junior |
| Eugene F. Hiller, Chicago | Junior |
| Frederick H. Avery, Chicago | Active |
| John C. Sanderson, Evanston, Ill | Active |

Also that the following applications for membership had been received:

| | |
|---|---|
| James E. Fulcher, Chicago | Active |
| Robert P. Durham, Chicago | Active |
| Lee Jutton, Oak Park, Ill | Active |
| Jerome A. Moskovitz, Belen, N. Mex | Junior |
| Fred H. Burgess, Lenox, Tenn | Junior |
| Hymen Fridstein, Chicago | Active |

Carlton F. Sherman, McComb, Miss., transfer............Junior to Active
Will O. Jacobi Chicago..........................................Junior
James McL. White, Urbana, Ill ......................................Active
Oscar F. Dalstrom, Chicago, transfer..................Associate to Active
Eugene A. Balsley Chicago, transfer........................Junior to Active
Alfred J. Saxe, Chicago...........................................Active
Albert F. Wright, Chicago........................................Active
Henry M. Morse, Chicago.........................................Active
Robert H. Kuss, Chicago..........................................Active
Wm. O. Hotchkiss, Madison, Wis...............................Active
Floyd S. Youtsey, Elgin, Ill.......................................Active
Joseph N. Pierce, Chicago....................................Associate
W. C. Robinson, Chicago..........................................Active
A. J. Sayres, Chicago..............................................Active
Raymond W. Hardenbergh, Chicago..............................Active
William H. Harris, Chicago.......................................Active
William H. Harris, Chicago.......................................Active
O. C. Spurling, Chicago...........................................Active

The Secretary presented the following resolution, which was in accordance with the By-Laws, regarding amendments thereto:

"*Whereas,* the present quarters of the Society are crowded; the meeting room is poorly adapted for our meetings; particularly in the matter of ventilation and acoustics; and more room is needed for our valuable and growing library; and,

*Whereas,* the present income of the Society should be increased to give greater facilities and advantages to our members;

*Resolved,* that the By-Laws of the Society be amended in the matter of fees and dues to provide an increase of the incomes of the Society.

*Resolved,* that the entrance fee for Active and Associate members be increased from $10 to $12.50. and for Juniors be increased from $3 to $5. Also that the annual dues of Resident members and Associates, be increased from $10 to $12.50, and of Non-resident members and Associates be increased from $7.50 to $8.50.

*Resolved,* that the amendments be sent out to the Active members of the Society for their adoption or rejection, by means of a letter ballot, in the manner provided for in the By-Laws. These amendments if adopted by letter ballot, shall be in force after January 1, 1907, excepting that such changes shall not apply for 1907 to those elected into the Society, whose applications for membership are now pending."

(Signed) W. L. Abbott,
Andrews Allen,
Albert Reichmann,
G. T. Seely,
E. N. Layfield,
O. P. Chamberlain."

This resolution was discussed by President Arnold, Vice-Presidents Abbott and Allen, Treasurer Reichmann, and Messrs. Bley and Belknap; the Secretary explained certain matters, and the condition of the Society. There was no amendment offered to the original resolution, so the Chairman put it to a vote, which was carried in the affirmative, and the Secretary was instructed to submit the amendment to the By-Laws, to a letter ballot of the Active members of the Society as provided for.

The meeting adjourned about 10 p. m.

The circular letter, the portion of the By-Laws as they would be when amended, and the form of secret ballot, for the adoption or rejection of the amendments, all as sent out to the Active members are herewith presented.

1734-41 Monadnock Block, Chicago.

CHICAGO, Nov. 10, 1906.

*To the Active Members of the Western Society of Engineers*:

At a regular meeting of the Society, held Nov. 7, 1906, a resolution, reduced to writing, and duly signed by six active members was presented and acted upon. This resolution amended Sections 1 and 3 of Article VI. to increase the fees and dues, as follows:

The "Entrance Fee" of Active and Associate members to be increased from $10.00 to $12.50; and of Juniors from $3.00 to $5.00.

"Annual Dues" of Resident Active and Associate members to be increased from $10.00 to $12.50; and of Non-resident Active and Associate members from $7.50 to $8.50.

These "Amendments" if adopted are to go into effect Jan. 1, 1907, but such increased entrance fees shall not apply to those whose applications are now pending.

The By-laws as amended are sent you herewith with a secret ballot by which you will vote whether or not you favor these amendments to the By-laws.

The arguments in favor of such changes in the fees and dues were set forth in the circular letter of Sept. 4, 1906. The object is to increase the income of the Society to provide greater facilities and better accommodations for our members, and place it on a yet higher plane than it now occupies. Our present income will not admit of any increase in our rentals but an increase will be necessary in the near future to provide greater accommodations for the growth in membership. Suitable and adequate quarters elsewhere, will probably cost three times as much as we are now paying. The arguments against such changes is the personal question, whether the membership in the Society will be affected by this increase of the fees and dues. The increase of the Entrance Fee only affects those who join the Society after the adoption of these amendments. The increase of the Annual Dues, will affect the Active and Associate members; those resident, to the greater extent, and to a less extent those non-resident.

This Society is not a club but essentially a Technical Society, with its headquarters in Chicago, the greatest center of engineering activity outside of New York. Here is maintained a suite of rooms for meetings and library purposes, which are open all business hours of business days, and with the Secretary and his assistants giving all their time and services to the interest of the Society. We own and maintain a free public reference Library, containing now over 6,000 volumes, many of great value, and which is being constantly augmented by purchase, donation, or in exchange for our Journal. The publication of the "Journal," is of great value to our members and the engineering world, but it is an item of considerable magnitude in the expenses of the Society.

In response to the circular letter of September 4, replies were received by postal card or letter from about 35 per cent. of the Active Members. Some of these replies, from members of standing in the Society, questioned the wisdom of increasing the fees and dues,—yet 85 per cent. of the replies, which include many eminent members, were in favor of an increase in one or more items of the fees and dues.

You will please give this matter your very prompt attention, returning your ballot, duly marked, by the enclosed envelopes. The ballots are to be canvassed by the Board of Directors, at their meeting, Dec. 4, 1906.

Respectfully submitted.

J. H. WARDER, *Secretary.*

## BY-LAWS WESTERN SOCIETY OF ENGINEERS.

Amend, Article VI. Sections 1 and 3. so they shall read as follows:

### ARTICLE VI.

#### FEES AND DUES.

SECTION 1. An entrance fee of twelve dollars and fifty cents ($12.50) shall be payable on admission to the Society by an Active member or Associate; and five dollars ($5.00) by a Junior; this sum to be credited against his entrance fee at the time of his transfer to another grade. A Junior's connection with this Society shall cease when he becomes thirty years of age, unless he be previously transferred to another grade.

SEC. 2. Honorary Members shall be subject to no entrance fees or dues.

SEC. 3. The annual dues payable by members shall be as follows: by Resident and Associate Members, twelve dollars and fifty cents ($12.50); by Non-resident Active and Associate members, eight dollars and fifty cents ($8.50); and by Juniors, five dolars ($5.00). Of these membership dues two dollars ($2.00) shall be set aside as subscription to the Journal.

Expunge Section 4.

Amend Sections 5 to 9 inclusive, by renumbering 4 to 8 respectively.

### BALLOT.

On the above amendments to the By-Laws increasing the
Fees and Dues, I vote YES
Put a X in one of the ( ) to indicate your vote. NO

### *MINUTES OF THE ELECTRICAL SECTION, November 16, 1906.*

A regular meeting of the Electrical Section (the 19th) being an extra meeting of the Society (No. 587) was held Friday evening, November 16, 1906.

The meeting was called to order by Mr. P. Junkersfeld, Vice-Chairman of the Executive Committee, about 8:15 p. m. with about sixty members and guests present.

The Secretary read the minutes of the meeting held October 19, 1906, which were approved. The Secretary also announced that at the December meeting of the Section it would be in order to put in nominations for the Chairman, Vice-Chairman, and one new member of the Executive Committee to serve three years, all to be voted on at the January meeting of the Section.

Mr. George A. Damon was then introduced who read his paper on "What is an Engineer-Constructor?" Discussion followed from Messrs. P. Junkersfeld, F. M. Davis, J. H. Warder, George R. Brandon, D. W. Roper, with a closure from Mr. Damon.

The meeting adjourned at 9:45 p m.

### *MINUTES OF EXTRA MEETING, November 21, 1906.*

An extra meeting of the Society (No. 588) was held the evening of Wednesday, November 21, 1906.

The opening of the meeting was delayed until 8:40 p. m. when Vice-President Andrews Allen called it to order; there were about seventy-five members and guests present.

There being no business to bring before the meeting, Mr. Edward W. DeKnight, of New York, was introduced, who read his paper on "Waterproofing, particularly as applicable to Masonry and Concrete Structures." There was some little discussion of the paper from Messrs. L. K. Sherman, W. H. Finley, Wm. Seafert, J. F. Strickler and G. B. Springer. Remarks were also offered in favor of special and proprietary methods and materials by Messrs. Fish, Palmer and others.

The meeting adjourned at 11:10 p. m.

### *MINUTES OF EXTRA MEETING, November 26, 1906.*

A special-extra meeting of the Society (No. 589) was held Monday evening, November 26, 1906.

The meeting was called to order at 8:15 p. m. with President Arnold in the chair, and about sixty-five members and guests present.

There was no business to bring before the meeting, so the president in a few suitable words introduced to the meeting Mr. R. S. Whipple, vice-president of the Cambridge Scientific Instrument Co., Cambridge, England, who read a paper on "Practical Pyrometry" or the measurements of high temperature. The address was illustrated by a number of lantern slides. Some apparatus was also on exhibition. including the Fery Radiation Pyrometer. A Resistance Electric Furnace had been installed to furnish the heat to show the working of this pyrometer.

The president and Messrs. W. C. Robinson, S. G. McMeen and J. H. Warder took part in the conversation which followed the reading.

The meeting adjourned at 9:45 p. m.

*MINUTES OF REGULAR MEETING, December 5, 1906.*

A regular meeting of the Society (No. 590) was held in the society rooms Wednesday evening, December 5, 1906.

The meeting was called to order about 8:25 p. m., with Vice-President Abbott in the chair and about fifty members and guests present.

Mr. Andrews Allen offered a motion that the chair appoint a committee of three members to canvass the letter ballots of the vote on the amendment to the By-laws in the matter of fees and dues. The motion was carried, and the chair appointed on the committee Messrs. D. W. Roper, W. M. Torrance and E. B. Wilson. who retired to count the ballots on this vote.

The minutes of the meetings of November 7, 21 and 26 were read and approved. The secretary reported from the Board of Direction the election into the Society of the following.

James E. Fulcher, Ann Arbor, Mich. .......... Active
Robert P. Durham, Chicago .......... Active
Jerome A. Moskovitz, Belen, N. M. .......... Junior
Fred H. Burgess, Lenox, Tenn. .......... Junior
Hymen Fridstein, Chicago .......... Active
Carlton F. Sherman, McComb, Miss, transfer from .......... Junior to Active
W. O. Jacobi, Chicago .......... Junior
James M. White, Urbana, Ill. .......... Active
Oscar F. Dalstrom, Chicago, transfer from .......... Associate to Active
Eugene A. Balsley. Chicago, transfer from .......... Junior to Active
Alfred J. Saxe. Chicago .......... Active
Henry M. Morse, Chicago .......... Active
Robert H. Kuss, Chicago .......... Active
William O. Hotchkiss, Madison, Wis. .......... Active
Floyd S. Youtsey, Chicago .......... Active
Joseph N. Pierce, Chicago .......... Associate
William C. Robinson, Chicago .......... Active
Albert J. Sayers, Chicago .......... Active
R. W. Hardenbergh, Chicago .......... Active
William H. Harris, Chicago .......... Active
O. C. Spurling, Chicago .......... Active

Also that the following applications had been received:

P. A. Degener, Chicago .......... Active
Geo. L. Sawyer, Lewiston, Idaho .......... Active
Harold H. Clark, Chicago .......... Active
Bert A. Gayman, Chicago .......... Active
John H. D. Petersen, Chicago .......... Active
Axel G. Johnson Rapp, Chicago .......... Active
James Hyslop, Harvey, Ill. .......... Active
Edward N. Lake, Chicago .......... Active
Albert H. Aldinger, Chicago, transfer from .......... Junior to Active
Charles C. Hotchkiss, Chicago .......... Junior
Wm. J. Miskella, Chicago .......... Junior
Edwin H. Smythe, Chicago .......... Active

Francis W. Lawrence........................................................Active
H. B. Otis, Chicago..........................................................Active
V. Y. Davoud, Chicago......................................................Junior
Walter F. Reichardt, Little Rock, Ark., transfer from......Junior to Active
Julius L. Hecht, Chicago.....................................................Active
H. R. Armeling, Minneapolis, Minn.......................................Junior
Melvin L. Enger, Minneapolis, Minn.......................................Junior
Harvey B. Fleming, Chicago.................................................Active

The secretary also reported from the Board of Direction the result of their canvass of the petitions received to nominate officers for the year 1907.

For President—Messrs. W. L. Abbott, J. W. Alvord and G. A. M. Liljencrantz.

For First Vice President—Messrs. Andrews Allen and C. F. Loweth.

For Second Vice President—Messrs. Geo. A. Damon, E. N. Layfield and A. J. Mason.

For Third Vice President—Professors I. O. Baker and A. N. Talbot.

For Treasurer—Mr. Albert Reichmann.

For Trustee for three years (one to elect)—Messrs. Andrews, Allen, W. C. Armstrong, A. Bement, C. B. Burdick and Louis E. Ritter.

The committee to canvass the votes for amendment to By-laws reported as follows:

Ballots counted as regular, 362.
Votes in favor of amendments to By-laws................276
Votes opposed to amendments to By-laws.................. 85
Void ........................................................... 1

362

The chairman then announced that as over seventy-six per cent of the ballots received were in favor of the amendments to increase the fees and dues, the amendments were approved and adopted; and would be in force with the beginning of 1907.

These amendments fix the entrance fee of Active and Associate members at $12.50; and of Junior members at $5; also the annual dues for Resident Active and Associate members will be $12.50; and of Non-resident Active and Associate will be $8.50.

There being no further business to bring before the Society, Mr. O. P. Chamberlain was introduced, who read his paper on Concrete Pipe Culverts, which paper had been printed and sent out in advance. Following the presentation of the paper the secretary read a communication from Mr. R. M. Hosea, M. W. S. E., Denver, Col., in discussion of Concrete Pipe Culverts. Oral discussion folowed from Messrs. Abbott, Cartlidge, Saxe, Talbot and Chamberlain.

Mr. T. L. Condron was then introduced, who presented an abstract of his paper on Tests of Bond Between Concrete and Steel, which was discussed by Messrs. Abbott, Talbot, Torrance, Boardman, Cartlidge and Sherman.

There was some lantern slide illustrations for both papers.

The meeting then adjourned at 10:45 p. m.

*MINUTES OF EXTRA MEETING, December 19, 1906.*

An extra meeting of the Society (No. 591) was held the evening of Wednesday, December 19, 1906.

The meeting was called to order about 8:20 p. m., with Vice President W. L. Abbott in the chair and about 25 members and guests present.

There was no business to bring before the meeting, so the chairman introduced Mr. F. W. Ruels of the University of Wisconsin, who read his paper on 'Vibrations of Passenger Trains from High Speed Electric Lighting Fngines." This paper, with its illustrations and diagrams, had been printed and sent out in advance of the meeting.

Discussion followed from Messrs. W. L. Abbott, J. H. Warder, W. E.

Symons, F. C. Harper, E. C. DeWolfe, J. A. Jamieson (of Montreal), and E. P. Marsh.

On motion of Mr. Layfield a vote of thanks from the Society was tendered Mr. Huels for his paper.

The meeting adjourned about 9:55 p. m.

*MINUTES OF THE ELECTRICAL SECTION, December 21, 1906.*

The twentieth meeting of the Electrical Section, W. S. E. being an extra meeting of the Society (No. 592) was held Friday evening, December 21, 1906.

The meeting was called to order about 8.30 p. m., with Vice-President W. L. Abbott in the chair, and nearly 100 members and guests present.

The minutes of the meeting, November 16, 1906, were read and approved.

The announcement was then made that it was in order to nominate for certain officers for 1907, to be voted on at the next meeing, to be held January 11, 1907. For the information of those interested, the secretary stated that the Section was under the management of an Executive committee, consisting of five members,—a Chairman, a Vice-Chairman (who each hold office for one year), and three others, one to be elected each year, and each to hold office for three years.

The Executive committee for 1905 consisted of:
W. B. Hale, Chairman.
S. G. McMeen, Vice Chairman.
W. G. Carlton (succeeded by P. Junkersfeld), for one year.
Geo. A. Damon, elected for two years, and
P. B. Woodworth, elected for three years service.

In 1906 the Executive committee consisted of:
S. G. McMeen, Chairman.
P. Junkersfeld, Vice Chairman.
Geo. A. Damon, hold over for that year.
P. B. Woodworth, hold over for two years, and
Otto Osthoff, elected for three years.

It was necessary now to make nominations for Chairman and Vice Chairman for 1907, and one other to serve on the committee for three years; to be voted on January 11, 1907. Some discussion followed, and the nominations offered by H. R. King, C. A. S. Howlett, R. F. Schuchardt and P. Junkersfeld, resulted in the following nominations:

For Chairman, 1907—C. A. S. Howlett.
For Vice Chairman, 1907—H. R. King, D. W. Roper and J. G. Wray.
For Member of the Executive Committee (for three years)—K. B. Miller and A. Scheible.

There being no further business, the chairman introduced Mr. R. F. Schuchardt, who addressed the meeting on "The Rotary Converter Substation; its Make-up and its Operation." This address was illustrated by lantern slides, and black-board sketches.

Discussion followed from Messrs. E. F. Smith, C. A. S. Howlett, P. Junkersfeld, D. W. Roper and the chairman, W. L. Abbott.

The meeting adjourned about 10:50 p. m.

J. H. WARDER, *Secretary.*

## BOOK REVIEWS.

General Specifications for Steel Railroad Bridges and Viaducts: New and revised edition, 1906. By Theodore Cooper. Engineering News Publishing Co., New York. 9½ in. by 7 in. Pamphlet. 36 pp. Price 50 cents.

The writer, with some trepidation, attempts a review of the above specifications written by such an eminent authority, but he cannot resist making one criticism in advance of the specification, in general, and that is the method of proportioning. In order to provide against the destructive action of the moving load, in all recent specifications, such as adopted by the American Railway Engineering and Maintenance of Way Association in 1905, the practice is to resolve the moving load into a fixed load, with a certain allowance made for impact and vibration. The designer then has three classes of loading to contend with, the fixed load, the moving load, and the allowance for impact; so that the sum of all these loads are simply considered as being static, and any unit stresses used are then the same as for a fixed load. The effect of wind pressure is also considered as a fixed load. It seems a pity that the author did not adopt this method of proportioning. By allowing one-half of the unit stress for the moving load as for the fixed load he is not consistent, for when he comes to proportioning his details he assumes the stresses for rivets, bearing on maosnry, bed plates and rollers low enough to take care of any allowance for impact which may be necessary, which to the writer does not seem to be quite consistent.

Under general description, Clause 1, the author permits the use of cast iron in special cases for bed plates. This should be confined to bed plates under fixed ends, in view of the fact that cast iron cannot be obtained sufficiently hard to resist the abrasion of the hard steel rollers under the movable ends of the bridge.

Clause 4 requires the head room in through bridges to be twenty-one feet above the *base* of the rail, whereas recent specifications require the clearance to be not less than twenty-two feet above the *top* of the rail.

Clause 5 requires the clear width to be fourteen feet, whereas recent specifications require this clearance to be fifteen feet.

Clause 7 requires the batter for the columns of trestles, towers, etc., to be not less than one horizontal to six vertical for single track bridges. This brings too much of an uplift, due to the wind, on the base of the columns, and the writer suggests that this be made one horizontal to five vertical.

Clause 16 requires the floor timbers from the center to each end of the span to be notched down over the longitudinal girders so as to reduce the camber in the track. This is the old way of reducing the camber in the bridge, but it seems much better not to put the camber into the bridge to begin with. In fact, it is a question in the writer's mind whether floor timbers should be notched at all unless they may be notched to clear the heads of rivets, for it is an easy matter to have the floor timbers dressed to uniform thicknesses so that notching will not be required.

Clause 46 says that no part of the web plate in the girder shall be estimated as flange area. This was almost the universal practice in former years, and was a feature which in many cases saved an old bridge from being condemned, inasmuch as the web plate was available in resisting bending in addition to carrying its share of the vertical load. It seems to the writer that in keeping with our present ideas, the web should be considered as doing flange duty.

Clause 47 provides against "shearing strain" on the web. This is an old story and it seems a pity that our specifications should speak of the shearing strain on the web in a girder when such a stress cannot possibly exist, inasmuch as a shear contemplates a sliding between two contiguous surfaces.

Clause 48 provides for stiffeners to be proportioned by a formula which would apply to stiffeners in a through plate girder as well as in a deck plate

girder, whereas it is well known that stiffeners in a through plate girder are not required at all excepting at the ends.

Clause 138 provides for the use of medium steel having an ultimate strength of 60,000 to 70,000 pounds per square inch. The author is to be commended for recommending this quality of steel, inasmuch as some recent specifications have adopted a much lower ultimate strength and the writer believes a much inferior material will be obtained under such specifications. More particularly is this applicable in the case of eye bars, which should have the ultimate strength of their material raised rather than lowered, owing to the fact that the process of annealing has a tendency to lower the ultimate strength.

Clause 144 permits the use of a low steel having an ultimate strength of 55,000 to 65,000 pounds per square inch, which is practically the same for the medium steel adopted by the American Railway Engineering and Maintenance of Way Association; so that what the author terms a low steel, is termed a medium steel by others. The use of this steel the author does not recommend, although its use is permitted, and the writer agrees with him, inasmuch as this material is certainly inferior to his medium steel when judged from a utilitarian standpoint.

To resume, the specifications are of a very high standard, and with the exception of the method of proportioning, are to be recommended for practice. J. W. S.

Manual of Field Engineering: Problems in Surveying, Railroad Surveying and Geodesy. By Howard Chapin Ives, Assistant Professor of Civil Engineering, University of Pennsylvania; and Harold Ezra Hilts, Instructor in Civil Engineering, University of Pennsylania. New York. John Wiley & Sons. Leather, 4 by 6½ ins.; pp. 136; with many illustrations. Price $1.50.

This book contains a series of problems in the various branches of surveying for use as a guide in field work in engineering colleges. Each problem is treated in the following order: Size of party, equipment, statement of problem, theory, and method of working out problem, with form of notes. There are 23 problems in plane surveying, 9 problems in railroad surveying, 11 geogetic problems, 6 astronomical problems, and 3 more elaborate problems on the method of conducting a farm survey, a hydrographic and topographic survey, and a railroad survey. The appendix treats of the adjustments of the engineer's transit and level. Seven tables are given for use with the barometer and in astronomical surveys.

The book does not take the place of a treatise on surveying or an engineer's field book, but explains in a clear, concise manner such fundamental problems as the student has time for in his engineering course. This book is of especial value to the student who can of necessity receive but a limited amount of personal instruction. The numerous and complete forms of notes is a feature to be especially commended. G. T. S.

The Principles and Practice of Surveying: By Charles B. Breed and George L. Hosmer, Instructors in Civil Engineering, Massachusetts Institute of Technology. New York, John Wiley & Sons, 1906. 6x9 inches. Cloth, 526 pp., with index. Price $3.00.

This book is not a treatise on surveying, although it covers quite fully certain of the more fundamental phases of the subject. The authors state in their preface that they have aimed "to produce a text-book which shall include the essentials of a comprehensive knowledge of practical surveying and at the same time be adapted to the use of teachers and students in technical schools."

The treatment of the ordinary or routine processes of field work, including chaining and the use of the level and transit, is about as complete as may be found in any treatise. However, the authors have erred in omitting from this book the presentation of the stadia and plane table methods of topographical surveying. A single paragraph is devoted to the stadia, while the plane table is not discussed at all, the authors stating that these sub-

jects are to be treated in a future volume entitled "Advanced Surveying." Owing to this omission it would appear that the volume now under review will not be well suited for general adoption as a text-book for use in technical schools.

Furthermore, if the authors saw their way clear to consider the use of the stadia and plane table under the head of advanced surveying, it is difficult to see why they should include in their more elementary volume a chapter on mining surveying.

Part I. is devoted to a description of the several instruments with the tests and adjustments of the same; Part II. contains a discussion of surveying methods; Part III. is given to methods of computing areas and volumes; and Part IV. to plotting mapping, indexing, filing, etc. The last 90 pages contain the usual trigonometrical tables and an index.

Aside from the defects above mentioned, this work deserves to rank with the better texts on this subject. Should the subjects reserved for the forthcoming volume be treated as fully as are those included in the first volume, there is reason to believe that the completed work will find a high place in the literature of this subject. W. D. P.

Batter Tables: For 192 batters from 1-16 in., 1-8 in., 3-16 in. to 12 inches per foot, giving altitude and hypothenuse in feet and decimals of feet for any base, measured in feet, inches and sixteenths, with table of equivalents of inches and fractions in decimals of a foot. By C. G. Wrentmore, C. E., Asst. Prof. of Civil Engineering, University of Michigan, Ann Arbor, Mich. Engineering News Pub. Co., New York. 1906. Quarto, Cloth Bound, 200 pages. Price $5.00.

This is a book of tables to facilitate operations in the draughting room, particularly applicable to laying out dimensions in frame structures. Each page contains two tables, one of altitude and the other of the diagonal (or the hypothenuse) based upon a specified batter, as measured on a base line. These batters range by sixteenths of an inch, from 1-16 in. to 12 in., to a batter of 12 in. to 12 in., with equivalent angles. These tables are not intended to take the place of tables of squares of which Buchanan's Tables was one of the first books to be published, and is well known to most engineers and draughtsmen in structural work, nor of tables of logarithms, but as supplemental to them. They are believed by the author to be of practical value, and economical of time and labor and are more accurate than if dependence were placed upon measurement of the diagonal (and other distances) of a scale drawing drawn at a reduced scale, as customary. With the sample drawing and explanation given in the beginning of the book, the use of the tables and their applicability in many other cases can be readily understood and used. The typography, presswork and paper are excellent, and the book should prove to be of considerable value in the draughting room. W.

Economics of Road Construction: By H. P. Gillette. Engineering News Publishing Co., New York, 1906. 6x9 inches. 49 pages, illustrated. Cloth $1.00.

The author of this work is favorably known by three others books which have come from the press during the recent past, pertaining to "Rock Excavation," "Earthwork and Its Cost," and "Handbook of Cost Data." This thin volume is "full of meat" for those concerned with the construction and maintenance of highways. The first chapter is introductory, and the next pertains to earth roads, which are of the greatest extent at this time throughout this country.

Gravel roads, which needs some attention, and in some fortunate districts can be had at a moderate cost, constitutes Chapter III.

Stone roads, "Macadam" and "Telford," occupy the next two chapters, and these are of interest to City Engineers, as well as County Road Commissioners. To a great extent in this western country the high cost of broken stone prevents the use of these forms of road construction. But the author

here as elsewhere, shows how economy may be had to reduce the first cost of such highways.

The three remaining chapters refer to "Repairs and Maintenance," "Improvements in Specifications," with a "Summary and Conclusions," as a finish to this admirable little book. It should be in the hands of all interested in "Good Roads." J. H. W.

ILLUSTRATED TECHNICAL DICTIONARY: By K. Deinhardt and A. Schlomann. Vol. I. Machine Details and Tools. McGraw Publishing Co., New York. 7¼ by 4¼ inches. Cloth, 403 pp. Price $2.00 net.

Technical Dictionaries have hitherto proved so unsatisfactory, that the German Society of Engineers was led to undertake, six years ago, the compilation of its monumental work, the "Technolexicon," which is now said to be nearly ready to go to the printer.

Meanwhile we have a competitor in a modest pocket volume of 400 pages compiled by K. Deinhardt and A. Schlomann, and issued by R. Oldenbourg of Berlin. It is Vol. I. of a proposed series intended to cover every branch of engineering in eleven volumes. The method adopted is new and consists in grouping the terms used in several branches. This first volume is devoted to "The Elements of Machinery." It contains the equivalent words in German, English, French, Russian, Italian and Spanish, and is supplemented with two alphabetical indexes, one covering those languages which print in Roman letters, and one in Russian characters. It is moreover illustrated with formulas and sketches in the text which make more definite the object to which the words apply.

The work seems to have been done with painstaking German thoroughness; the price is small and the members of the Society are invited to inspect the volume now in the library of the Society. O. C.

STRAY CURRENTS FROM ELECTRIC RAILWAYS: By Carl Michalke, translated and edited by Otis Kenyon, New York, McGraw Publishing Company, 8¼ by 5¾ inches, 101 pp., including Index, Illustrations, Formula and Bibliograph. Cloth, price $1.50.

In the author's preface, it is stated in substance that the book is a compilation of much that has been written in the different periodicals concerning leakage currents from electric railway returns and does not pretend to give any general method of preventing the disturbance since many factors, which depend upon local conditions, enter into the problem. The book should, however, supply information on any one of the different parts of the subject.

In the translator's preface, it is stated that "electrolysis is a disease most largely peculiar to America, and, therefore, a book such as Dr. Michalke has produced is of prime interest to us." The contents are divided into twelve chapters as follows:

I. Introduction. II. Stray currents with uniform current load on the rails. III. Stray currents with uniformly increasing current load on the rails. IV. Resistance values. V. Distribution of potential in the earth. VI. Corrosion currents. VII. Corrosion currents which do not come from railways. VIII. Corrosion. IX. Measurements. X. Preventative measures. XI. Other disturbances caused by stray currents. XII. Conclusion, Bibliograph, Index.

All useful information bearing on the subject is of interest and is gratefully accepted by the American interested in the protection of underground metal pipes from corrosion caused by stray currents, and there is much useful information in the book, although in the opinion of the reviewer, if condensed and the mathematical formula for calculating the approximate value of stray currents under conditions never met with in practice were cut out, it would be most acceptable and useful to the average American engineer.

Chapters IV., V., VI., VIII. X., and XII. contain much that is interesting and while the author's preface states that "no general method of preventing the disturbance is given," yet as a matter of act, several methods of wholly

or partially reducing the current flow to and from and through the underground pipes are given, such as complete insulation of both outgoing and incoming electric railway conductors, partial insulation of the rails by a roadbed of asphaltum concrete, partial insulation of the underground pipes by coating with insulating paints, increasing the conductivity of the return conductors that should carry the current by placing auxiliary copper conductors, increasing the mass of the rails and proper bonding, decreasing the conductivity of the pipes that should not carry the current by putting in occasional sections of nonconducting pipe, insulating the joints, etc., etc.

The following are extracts from Chapter XII. Conclusion:

If the rails used to carry return currents are not fully insulated from the earth, it is impossible to entirely prevent the leakage of current. Also, if the pipes are not perfectly insulated from the earth, stray currents cannot be prevented from entering them. Earth currents can only be entirely prevented when both positive and negative conductor are insulated, as may be done in conduits in cities and with two trolleys outside."

"What precautions are to be taken must be determined from a consideration of the local conditions so as to best satisfy the interests of all concerned."

"Both the railway company and the companies operating the pipe lines must co-operate in determining the preventative measures to be employed, since each can do a great deal to reduce or remove the danger of corrosion."

The Bibliography added by the translator is a valuable directory of the numerous articles written on this subject. W. C.

Five Figure Logarithms of Numbers and Angular Functions, for the Use of the Engineer, Constructor and Student: By Henry Harrison Suplee. Philadelphia, J. B. Lippincott Company, 1906; flexible leather, 91 pp, 4¼ by 7 inches. Price $2.00

This book of tables is a small handy one, that, with its leather binding, can be readily carried in the pocket for field use. The tables give a range for numbers from 100 to 1,000, and of the six angular functions of all angles, varying by degrees and minutes. A table of hyperbolic logarithms is also given of numbers 1.01 to 9.99, varying by hundredths, and of whole numbers from 10 to 134. There are about fifteen pages of explanation of the tables and their usefulness, which make the book of greater value to those who, being long out of practice of the use of logarithms, may forget involved calculations. The book is not intended to take the place of such tables as Vega's, but as supplemental thereto for handy use, when the bulky volume would not be available. W.

Steam Turbines and Turbo Compressors, Their Design and Construction. By Frank Foster, M. Sc. 449 pp. ix, with 240 illustrations, The Scientific Publishing Company, Manchester, England. Price 10/6.

Quite a number of books on the Steam Turbine have seen the light during the last few years, and it probably will be some time yet before the field will be covered in an entirely satisfactory manner. This is but natural as the progress in the development of the steam turbine, both in design and theory, is still very rapid. Mr. Foster's book is a welcome addition to the literature on the subject, not so much because it contains such a very large amount of original matter, as the author evidently imagines it does, but because it has brought together, in a convenient form, a good deal of information which otherwise, to a certain extent at least, was difficult of access. This is notably true with reference to the chapters treating of "blades" and "condensers." In the chapter on "rotors" the author introduces some mathematical developments which require the knowledge of both integral calculus and differential equations. It is to be expected that the practicing engineers, for whom the book is written, will not find this very much to their taste. Otherwise this very chapter contains some very useful information.

The Chapter on "Steam Turbine Performance" is very good so far as it goes, but does not contain nearly as much information in this line, as some other books recently published.

There is a chapter on "Marine Turbines," but curiously enough the major portion of it is occupied by a discusson of the ship propeller, the turbo compressor, and the gas turbine. It may be noted that the author expresses the opinion "that there is no hope that a gas turbine (working between the same pressure limits) can beat the reciprocator so far as efficiency goes"—an opinion which in the mind of the reviewer is altogether premature, and for which the author does not give adequate reasons.

In the next chapter, the title of which is "Diagrams and Calculations," the most noteworthy parts are two numerical examples of the computation of a reaction and of an impulse turbine; the new heat diagram proposed by the author is, in the opinion of the reviewer, not as useful in the computation of the steam turbine as the modified temperature—entropy diagram of Mollier accompanying Stodola's book on the steam turbine.

The chapter on "Construction" contains a large number of practical hints which will be found very valuable for the designer. The history of the steam turbine contained in the last chapter is too brief to be of any particular value.

In no other book, published originally in the English language is the distinction between the reaction and impulse turbines made so clear as in this book, and the author has very clearly explained the action of the steam during its passage through the various kinds of turbines. The description of these turbines is quite satisfactory, although it would have been an advantage if a few more turbines had been described.

The illustrations are, on the whole, fairly satisfactory, but, as in so many books, there are too many "pictures" which are of very little value to the designer. The book is well gotten up, both as to paper and print, and its price is moderate. S. B.

Outlines of Practical Sanitation for Students, Physicians and Sanitarians. Dr. Harvey B. Bashore of the Pennsylvania Department of Health. New York, 1906, John Wiley & Sons. Cloth 7½ by 5 in. pp. 208 with 42 illustrations. Price $1.25. This is a companion book to another by the same author, "The Sanitation of a Country House" reviewed in this publication, last year; Vol. X, page 570.

The book is pleasantly written and contains some excellent advice on sanitary matters, and consists of twelve chapters, which treats of subjects under the headings of "Habitations," "Water Supply," "Collection and Disposal of Waste," "Milk Supply," "School Sanitation," "Car Sanitation," "Cause and Prevention of Contagious and Infectious Diseases," "Vital Statistics," "Municipal Sanitation," "Rural and Suburban Sanitation" and "Personal Hygiene." There are some good and pleasing illustrations through the text, generally half-tone reproductions of photographs. This is not an exhaustive treatise, but a convenient little hand-book, design particularly for the layman, the every day men and women, who make up the great bulk of our communities, and who are sufficiently intelligent to read and comprehend what the author wishes to impress on the people at large, "Practical Sanitation" the observance of which has so much influence on our well being. The subject of water supply, its purity, etc., has been frequently presented but the subject of food and milk supplies are not as often considered as they should be; again, as Americans are great travelers, the chapter on car sanitation is of value, both to the traveler and to the manager and his assistants of the various lines of transportation, whether urban, suburban or interstate.

It is hoped that the book may be well circulated and generally read, for if the principles here presented are understood and acted upon, the general health of present and future generations should be greatly improved. W.

Fowler's Architects and Builders' Hand-Book. Scientific Publishing Co., Manchester, England, 526 pages, leather bound. Price, 3 shillings, 6 pence.

This is a work of some five-hundred pages, pocket book size bound in leather. The first eighty-five pages are devoted to weights and measures, mensuration, rules for drawing the simple geometrical figures and some miscellaneous information and tables.

The balance of the book is a series of chapters relating to the simpler forms of building construction. Under brick and brick laying all of the old English bonds are quite clearly illustrated and a chapter devoted to the arch and its architectural variations gives simple rules for drawing their various forms. Under the head of Masonry, English stones with their location and characteristics are completely listed. Stairways, arches, columns, mouldings in wood and brick are each treated in some detail and under timber, English, Canadian, Australian, and woods of the Continent are given considerable space. Painting and decorating is covered in a chapter of some forty pages followed by about the same space devoted to the various styles of architecture and the Classical Orders.

There appears to be but slight mention of some of the most important details of present day practice. A few pages are devoted to steel, giving its density, expansion, specific heat, weight, etc., but the Author makes but little application of its use in building construction and the various steel shapes are not mentioned excepting a short table of weights and strengths of rolled joists.

No example of mills, factories or other buildings requiring special details or fire proof construction are given. Reinforced concrete is not mentioned and the few pages devoted to plain concrete work can hardly be considered adapted to present day practice. Electric lighting, building elevators and such modern necessities are given but a few pages.

The Author states that this is a synopsis of practical rules, tables, and data compiled for the use of architects, builders, plumbers, painters, decorators, and students in technical schools. It is the opinion of the reviewer that as a hand book for artisans and skilled laborers engaged in the various building trades it is a cheap and excellent compilation of English practice, but it is so extremely local in its application and so elementary in its treatise of all technical subjects that the architect and student would find it of little value. It is well indexed but the scheme of mixing advertisements with the index is one to be condemned. G. H. H.

Catechism on Producer Gas. by Samuel S. Wyer, M. E. The McGraw Publishing Co., New York, 1906. Cloth, 6¾ by 4½ ins. 42 pages. Price, $1.00 net.

This book will be welcomed by a large number of Engineers who are anxious to obtain a practical knowledge of the various kinds of Gas Producers and of the principles of their operation.

This method of presenting the subject is most useful to the operating engineer as there are many questions answered in it that are being constantly asked by both purchasers and consulting engineers.

The answers are entirely free from theoretical matters and are given in a clear and accurate manner. L. P. B.

Handbook of Mathematics, for Engineers and Engineering Students: by J. Claudel. From the 7th French edition, as translated and edited by Otis Allen Kenyon, New York, 1906. McGraw Publishing Co., 708 pp.; 422 figures in text; 8vo.; cloth. $3.50 net.

The busy engineer in actual field practice is very apt to forget some of his earlier mathematical instruction, and would often like to have on hand, within easy reach, a brief resume of his college mathematical text books. The above described handbook is intended to furnish just such a resume, and it does so to a large extent. The work covers briefly, Arithmetic,

Algebra, Plane and Solid Geometry, Plane and Spherical Trigonometry, Analytic Geometry and Differential and Integral Calculus; giving the fundamental principles of each subject, and illustrating each step by pertinent practical examples. Useful tables are scattered through the book, amongst which are notably, those of prime numbers, compound interest, functions of Pi to 7 decimals, lengths of arcs to 12 decimals, natural trigonometry functions to 4 decimals, and the most used simple integrals and differentials. Under the head of Arithmetic are given almost all of the so-called short methods for rapid calculation and check of final results. The book is not intended to take the place of elementary text book, nor of the higher grade to text books, nor of special engineering note books; but it is well adapted to allow the average field engineer to rapidly refresh his memory as to the fundamental principles of each subject; a matter which the other books give in either too detailed or too brief shape for quiet reference. B.

ELEMENTS OF GAS ENGINE DESIGN: By Sanford Moss, M. S., Ph. D. D. Van Nostrand Co., New York, 1906. 4 by 6 inches, boards, 200 pp. 50c.

This is a recent addition to the Science Series, and is a publication treating of all the fuels used in the internal combustion engines; also of gas producers which furnish power gas, with the combustion reaction and tables which give the heat value of all commercial gases. The book explains the thermodynamics of gas engines in plain English and by the use of simple formulae, so that the perusal of the work is interesting throughout. While the work deals mostly with small engine design, the theories are applicable to engines of any size. The work is a valuable one and of all the literature on internal combustion engines it should be the first read by the student who desires to become familiar with the prime mover of the future. The text consists of XIV. chapters, of which I. to V. give a general outline of the physics and chemistry of the gas engine and a discussion of the gas engine fuels, with sundry tables, of which, table 3 shows the relative power yielded by various fuels in a given engine. In the chapters following, up to IX., is discussed the action in a gas engine cylinder from the point of view of the designer, and chapter X. presents the method of finding the size of cylinders for a given power. Further, chapter XIII. outlines rather briefly the more important principles of gas engine construction followed (in XIV) with rational formulas for most parts of a gas engine, all conveniently arranged for the designer's use. It is regarded by some experts as the best publication at this time for one desiring to become familiar with gas engine practice. C. E. S.

ELEMENTS OF GENERAL CHEMISTRY: By Prof. John H. Long, Northwestern University, Evanston, Ill. Fourth edition, 1906. 8 by 5½ inches. 443 pp. with index. Cloth, $1.50 net.

ANALYTICAL CHEMISTRY (textbook); Qualitative and Volumetric, by the same author. Third edition. 1906. 8 by 5½ inches. 300 pp. with index. Cloth, $1.25 net. P. Blakiston's Son & Co., Philadelphia.

The "Elements of General Chemistry" is specially adapted for use as a textbook for the student, though its style and method of presentation are more practical than is usual with a school textbook. It is therefore well adapted to the wants of the engineer who desires a handbook for reference, or for the study of the principles of chemistry and the properties of the elements and their compounds. The book contains 24 chapters, of which the first is introductory of 30 pages of essential value to the student or even to review to refresh one's recollections of experimenattion and the foundations of chemical science. The explanations and descriptions of experiments here and throughout the volume is a valuable feature of the book. The various chemical elements grouped in a logical manner are treated in subsequent chapters, in a way to be readily understood by the student.

The "Analytical Chemistry" is a natural sequence to the first book noted and embodies the principles of analysis, the result of the author's long experience as a teacher of chemistry. The book is intended for students who are familiar with elementary chemistry. The author believes it to be use-

ful to present to students of qualitative analysis, more or less volumetric work, and this book is arranged with this in view. Though teachers may differ with Prof. Long as to the value of this method of instruction, the work may be found valuable to engineers and others who desire to take up the subject matter; the work, however, seems to be more particularly adapted to students of chemistry in pharmaceutical and medical colleges.

H. & W.

Universal Dictionary of Mechanical Drawing: By Geo. H. Follows, New York, 1906. The Engineering News Pub. Co. Cloth, 8 by 11 inches, Oblong. 60 pp. Price $1.00.

Although there are many books on mechanical drawing offered the public, this dictionary, as the author chooses to call it, is worthy the attention of the man experienced in the art as well as the beginner. While previous authors have furnished the student with a number of figures or plates to copy, the author of this book lays particular stress on the construction of the drawing, i. e., simplicity and plainness are presented so that drawings made after the author's suggested schemes will be readable by any that use them. The book might be called a proposed system of standards, submitted to the drafting fraternity to be used in their daily work and if all that use drawings were conversant with some such system no trouble would be experienced by a man changing his position as is now the case where every office has its own standards and pet methods of making drawings.

The subject matter of the book is listed in the following chapters:

Chap. 1. Introduction and an alphabet.
Chap. 2. Letters and lettering.
Chap. 3. Figures and dimensions.
Chap. 4. Projection and projection views.
Chap. 5. Sectioning and sectional views.
Chap. 6. Finishes and the finish mark.
Chap. 7. Dimensioning.
Chap. 8. The record strip.
Chap. 9. Nomenclature and written matter.
Chap. 10. Checking.
Chap. 11. Standard data.
Chap. 12. Example drawings.

**H. A. J.**

## NEW EXCHANGES.

Putnam's Monthly: A new candidate for public favor in the line of general periodical literature is "Putnam's Monthly and The Critic," published in New York, by G. Putnam's Sons. This magazine is of about the same size as the well known "Century" but is less expensive, only $3.00 per year, or 25 cents a copy. It is now many years since the original "Putnam's" was published. There were some giants among the early writers—Parke Godwin, George William Curtis, James Russell Lowell, Thoreau, Longfellow, Stoddard, Stedman, were among these—but the commercial depression of the country between 1855 and 1860 led to the suspension of this early example of monthly magazines. The Putnams issued for many years a critical literary monthly, called "The Critic," which is now incorporated with this new candidate for public favor. The high literary and critical character of "Putnam's" should command attention and create a clientele that will be a support for this among the great multitude of magazines to be seen on the news counters.

In the three monthly numbers issued at the end of 1906, there is some fiction of a high quality, but the greater portion of the reading matter is of a fairly serious order; but is enlivened with good illustrations. A portrait and three addresses of the lamented John Hay, Stoddard's last poem, with a portrait; Franklin's "Social Life in France;" "The Man with the Muck-Rake," by President Roosevelt, in its final and amended form; "The Latin and Teuton Races" by Maeterlinck, and "Lafcadio Hearn,—a study of his personality," are some of the articles in the October issue.

The November number continues the series of Franklin and Lafcadio Hearn,—a paper on "The Charm of Rural England," "The Reading Habit in the United States," with illustrative diagrams, a continuation of the novel "The Shadow of a Great Rock" and a striking poem by Ethel Morse, on the "Statue of Liberty," besides other matter of minor mention.

The "Christmas," or December issue, contains ten American Paintings of Christ, reproduced admirably within the limitations of half-tone work, with text by Saint Gaudens; also an illustrated article on Corot, with portrait; an informal address, "The Kingdom of Light," delivered before a gathering of friends by George R. Peck; a further installment of Franklin's "Social Life in France." and the novel—"Shadow of a Great Rock;" "The Mahogany Tree," an illustrated poem by Thackery, very appropriate just now, with sundry articles of a critical nature or of a biographical interest, help fill this number and give most excellent reading.

Our congratulations go out to the publishers for what they have thus far presented to the reading public, and our best wishes that they may have the success that such a magazine deserves, and be rewarded for their labors.

## TRADE CATALOGUES.

Chester B. Albree Iron Works, Alegheny, Pa. Catalogue No. 6, oblong, 6 by 9 inches, 56 pages illustrated. Descriptive of "Pittsburg" riveting machines of pneumatic operation; many types and sizes are shown, suitable for various classes of work. Most of these illustrations are of portable or semi-portable machines, but some massive stationary machines are included in the list of "Pittsburg" riveters.

An interesting feature of this catalogue is certain tables showing pressure on rivets to be had with different sizes of machines, and at different portions of the stroke air consumption and pressure required to drive rivets of different diameters. There are 18 pages and one double page inset giving information and tables on rivets and riveting compiled from various sources, and here presented for the benefit of the detailer in the drafting room, or the foreman in the bridge shop. These tables and diagrams should be of sufficient value as to create a demand for this catalogue.

"Thor Pneumatic Tools; Independent Pneumatic Tool Co., Chicago and Aurora, Ill. Catalogue No. 7, 9 by 12 inches, 12 pages illustrated. of Piston Air drils, reversible and non-reversible, including portable wood boring machines and pneumatic hammers, for chipping, calking and riveting. Also portable pneumatic grinding machines, and a pneumatic saw, useful to carbuilders, shipbuilders, etc., cutting and trimming roofs, sides, doors, etc. The many illustrations in this booklet are well executed half-tone cuts, and illustrate different types and sizes of these tools and their varied applications. The sectional illustrations and description of the machines, whether hammers or drills, would indicate to the layman that these tools possess some advantages over other and similar tools.

The Ingersoll-Rand Co., New York, successors of the long established Ingersoll-Sergeant Co., of New York, issue sundry bulletins illustrative of their tools and the work done.

*Bul. No. 2002*—describes the track-laying on the Williamsburg Bridge, New York. The pneumatic drills are shown drilling the rails for the fish plates and for the bond wires, the boring of bolt holes in the wooden ties, and for the guard rails.

*Bul. No. 2003*—describes pneumatic hammer drills of a special constructoin and known as the "Little Jap." These may be hand tools or of a larger size, mounted on a column or tripod for mine or quarry work. Duplicate part list, with illustrations, name and code-word of these tools, is included in this bulletin.

*Bul. No. 2004*—describes stone working tools which are essentially pneumatic hammers, but modified to suit the conditions for chipping, dressing and drilling in stone, in stone yards as well as in quarries. The pneumatic principle of operating stone cutting tools is very applicable in the carving of

stone capitals and the like, being far superior in operation, and cheaper in hand work.

*Bul. No. 2006*—describes the "imperial pneumatic hammer" for riveting and chipping work. The illustrations show their use in structural steel work.

*Bul. No. 2007*—describes the "imperial piston drills" for drilling, reaming, tapping, etc. These are of the reciprocating piston type, and of various sizes and capacities. Illustrations show the use of these tools in a variety of applications. Though generaly portable, and handled by the workman at the work, the catalogue also shows a radial drilling frame of a simple design and construction, but which should be very "handy" in many machine shops. Sundry pages show "repair parts" of different sizes of the imperial drills with name and code-word.

*Bul. No. 2008*—relates to imperial motor hoists and stationary motors. The motor hoist consists of a high-duty pneumatic motor of the balanced three-cylinder construction, operating with a very moderate air consumption. This is geared to a hoisting drum by a mechanical arrangement, to give a high economy of power. The design also includes moderate weight, minimum dimensions, low head room, perfect control, steadiness in operation, with simplicity and durability. These hoists can be suspended from a trolley, carried on an overhead rail and have a considerable range of lift and travel. These are built in five sizes, from 1,000 to 10,000 pounds capacity. The stationary motor contains the same essentials as the motor hoists of the three-cyclinder mechanism, but is intended to give power by a shaft and pulley at some fixed point, as the name implies. It is a valuable tool under many conditions.

The Chicago Pneumatic Tool Co., Fisher Bldg., Chicago. Catalogue No. 20, October, 1906. Describes in detail and with many beautifully executed illustrations the Air Compressors, as made by this company at their shops, Franklin, Pa. It is a book of 116 pages, 6 by 9 inches, with stiff paper cover. The design and constructive details of the Franklin Compressors are well brought out in the book. The various types include steam motor and gas engine, driven with simple and more complex types of valve gearing, as may be best adapted to the requirements. Some pages of this catalogue are given to the subject of pumping by compressed air, describing the "Chicago Water Lift." Numerous interesting tables and formulae are introduced, which render this handsomely printed catalogue of greater value to those interested.

Catalogue No. 17, November, 1905, of the same Company, shows that the Company organized in 1902 consists of the consolidation of the original Chicago Pneumatic Tool Co., The Boyer Machine Co., of Detroit, the Moore Pneumatic Crane Plant at Cleveland, Ohio, The Franklin Air Compressor Co. of Franklin, Pa., and also the Standard Pneumatic Tool Co.. Chicago, The Philadelphia Pneumatic Tool Co., Philadelphia, and the Keller Pneumatic Tool Co. of Philadelphia.

This book is of the standard size 6 by 9 ins., and contains 192 pages, with many illustrations, of the various machines manufactured, of their several parts and of their applications. Tables are also given with numbers referring in detail to repair parts and code-word for ordering them. The Boyer Riveting Hammers are first described, of various types and sizes. with diagrams of chipping, calking and beading tools. Tables are also presented of work done, and cost of same. Then follows the illustrated descriptions of the Keller Tools—riveting, chipping and calking hammers of various sizes and adaptations. Also the Little Giant Drills reversible and non-reversible. The Boyer Piston Air Drills follow with descriptions. The Duntley Electric Drills of various sizes and capacities are made by this company and are described in this list.

Sand Rammers for use in foundries and in concrete work is a new application of pneumatic hammers. These, under the trade name of "Chicago" and "Keller," are described and their use illustrated. Pneumatic

geared hoists is a modified application of the reversible three-cyclinder air engine used with air drills, except that the "motor" is of a two-cylinder construction. These tools would seem to be very convenient and applicable in many forms of crane work. Of a different type is the cylinder air hoist, when the air pressure is applied to a piston working in a long cylinder of such size as to give the lifting capacity, and of a length to give the lift required. These air lifts may be vertical, suspended from the gib of a crane, or carried by a trolley from an overhead rail. Other modifications of these are designed for elevator purposes, when a platform is attached and where the lift may be, say, 10 ft. to 20 ft. in height, applicable in foundry work to lift the iron, coke, etc., to the cupola charging floor. Altogether these two catalogues give much valuable information of the tools, appliances and applications for the use of compressed air.

CLEVELAND PNEUMATIC TOOL Co., Cleveland, Ohio. Catalogue F, oblong, 6 by 9 ins., 64 pages and stiff cover; describes the "Cleveland" chipping and riveting hammers and drills, also hose couplings and other pneumatic appliances. These include stone and scaling hammers, calking hammers for light work and flue beading, and general chipping and calking work, also others for heavier work. The half-tone illustrations show machines of different sizes and capacities which represent pleasing outlines and would appear to be efficient tools. There are two forms for operating the air valves; one, shown with the lighter tools when the air admission is under the control of the thumb and outside the handle; the other, when the valve is worked by the grip of the fingers inside the handle. The pneumatic drills are made breast drill form in some of the smaller sizes, but the heavier sizes are provided with screw feed. These tools should be very valuable in the machine shop, as well as in field construction, because of their portability, and only requiring a lead of hose to supply the air for their operation.

BENJAMIN WIRELESS CLUSTERS AND LIGHTING SPECIALTIES. *Catalogue B-17, November, 1906.* Benjamin Electric Mfg. Co., Chicago, New York and San Francisco. Pamphdet, 6x9 ins., 104 pages, fully illustrated.

This catalogue is of value to the Architect and the Electrical Contractor concerned in electric lighting installations, whether in buildings, cars or vessels. There are shown various forms and styles of Cluster Bodies to provide for a number of lamps from one outlet; also Ceiling Forms, with reflectors and shades of various shapes, including globes. Again, Part III. relates to Pendant Forms, also provided as above with shades, reflectors and globes. Part IV. illustrates Weatherproof Forms for use in exposed positions. Part V. shows forms of Arc-Burst for interior and exterior illumination, of pendant, suspension, and weatherproof form. Many other specialties—fittings, brackets, receptacles, sockets, guards, etc., etc., are shown and listed, and make this catalogue a valuable one to those interested in such matters.

TECHNICAL THERMOMETRY. List No. 39. The Cambridge Scientific Instrument Co., Ltd., Cambridge, England. 1896. Pamphlet 8½x12 inches, 62 pages, including index, and many illustrations. Chicago, The Scientific Shop, A. B. Porter, M. W. S. E., 324 Dearborn St.

At a recent extra meeting of the Western Society of Engineers, Mr. R. S. Whipple, of Cambridge, England, presented a very interesting paper on "Practical Pyrometry," or the measurement of high temperatures. On that occasion, by means of lantern slides and of the actual apparatus, much valuable information was given of the measurement of temperatures. This catalogue lists the apparatus shown and others under the different classes of Electrical Resistance, Thermometers, Thermo-Electric Thermometers, Fery Radiation and Absorption Pyrometers, Continuous Temperature Recorders, Electrical Resistance Furnaces, etc. The illustrations show the construction and use of the apparatus. Prices are given both in Sterling and U. S. Currency; and a long list shows very diverse manufacturing es-

tablishments which find it "good business" to employ more or less of such apparatus as is listed in their manufacturing operations, to note and have under control the temperatures of these various operations. A full page table on page 57 gives the relative values or a comparison of thermometric scales,—Centigrade and Fahrenheit—from 20° C.=—4° F. to 2000° C.= 3632° F. Though but a "trade catalogue" this pamphlet presents much of interest to the Engineer, particularly if he be concerned in chemical, metallurgical or manufacturing interests, where the temperatures of the operations is of consequence.

---

## LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for October, 1906, we have the pleasure to report the following additions to the library and gifts from donors named:

### MISCELLANEOUS GIFTS.

Ball, C. B., Chicago, "A Plumbing Catechism," by Ball and Sherriff. Cloth.

Tratman, E. E. R., M. W. S. E., Chicago, "Cape Government (Africa) Railways. Reports of Test Trains, 1905 and 1906. Pam.
- Advance paper, Institution of Mechanical Engineers, London, "Liquid Fuel Locomotives (petroleum) on National Railroad of Mexico." Pam.
- Water Supply & Irrigation Papers No. 180, 181, and 186. Pam.
- Experiments on the Strength of Treated Timber, by W. K. Hatt. Pam.
- Report of the New South Wales Railway Commissioners for the year ended June 30, 1906. Pam.
- Contributions to Economic Geology in 1905. Bulletin 285, U. S. Geological Survey. Pam.

Scientific Publishing Co., Manchester, Eng., "Fowler's Architects and Builders Handbook." Leather.
- "Corrosion and Protection of Metals," by A. H. Sexton. Cloth.

McGraw Publishing Co., New York. "Handbook of Mathematics," by Claudel. Cloth.
- "Stray Currents from Electric Railways," by Michalke. Cloth.
- "Illustrated Technical Dictionary" Vol. I., Elements of Machinery, by Deinhardt and Schlomann. Cloth.
- "Catachism on Producer Gas." Wyer. Cloth.

Engineering News Publishing Co., New York, "General Specifications for Steel Railroad Bridges and Structures," by Bogue and Buel. Pam.
- "General Specifications for Steel Railroad Bridges and Viaducts," 1906. Theodore Cooper. Pam.
- Batter Tables, by C. G. Wrentmore. Cloth.
- Economics of Road Construction, by H. P. Gillette. Cloth.
- Reinforced Concrete; revised edition 1906. Buel and Hill. Cloth.
- Railroad Curve Tables, by R. S. Henderson. 1906. Cloth.

John Wiley & Sons, New York, "Outlines of Practical Sanitation," by H. B. Bashore. 1906. Cloth.
Problems in Surveying; Railroad Surveying and Geodesy, by H. C. Chapin and H. E. Hilts. 1906. Morocco.
The Principles and Practice of Surveying. By Breed and Hosmer. 1906. Cloth.
Myron C. Clark Publishing Co., New York. "Railroad Location, Surveys and Estimates," by F. Lavis. 1906. Cloth.
Bates, William S., M. W. S. E., Chicago. "Manual of Heating and Ventilation," by F. Schumann, New York. 1877. Leather.
Brunner, John, M. W. S. E., Chicago.
"Report, Department of Public Works, Bureau of Filtration, Pittsburg, 1902." Pam.
"National Geographic Magazines," July and August, 1906. 2 Pams.
Iowa State College, Engineering Experiment Station, Bul. 6. Vol. 3, "The Assessment of Drainage Districts." Pam.
West, Oscar J., M. W. S. E., Chicago. "Handbook, Phoenix Iron Co. of Philadelphia, 1906." Morocco.
Milton E. Lowitz Publishing Co. Chicago. "The Western Blue Book, 1906." Cloth.
Michigan College of Mines, Houghton, Mich., Year Book, 1905-6. Book of Views. 2 Pams.
Strobel, C. L., M. W. S. E., Chicago. "Roll-turning for sections in steel and iron," by Adam Spencer. 1891. Cloth.
Hermany, Chas., Chief Engineer and Supt., Louisville Water Co. Reports for years 1900, 1902-3-4-5. Five Pams.
University of Illinois, Engineering Experiment Station, Bul. 5. Resistance of tubes to collapse, June, 1906. Pam.
Warder, J. H., Sec'y W. S. E., Chicago. Smithsonian Report on "Recent Improvements in the Chemical Arts," by Booth and Moffit, 1851. Cloth.
Davies, Edgar T., Chicago. Inspection of factories and Workshops in Illinois, 11th and 12th annual reports, 1903 and 1904. 2 vols. Cloth.
Bureau of Engineering, Department of Public Works, Buffalo, 13th annual report, 1905. Pam.
George W. Jackson, M. W. S. E., Chief Engr., Illinois Telephone Construction Co., Chicago. "Chicago Subway." Pam.
John V. V. Booraem, Brooklyn, N. Y. "Internal Energy," by Booraem. 1906. Cloth.
P. Blakiston's Son & Co., Philadelphia, Pa. A Text-book of Elementary Analytical Chemistry, by J. H. Long. 1906. Cloth.
Iowa State Board of Railroad Commissioners, 28th annual report, 1905. Cloth.
Massachusetts Board of Health, 37th annual report, 1905. Cloth.
Maj. F. M. Kerr, Chief State Engineer, New Orleans. Reports, Board of State Engineers of Louisiana for the years 1888-90; 1890-92; 1892-94; 1894-96; 1896-98; 1898-1900; 1900-1902; 1902-1904; 1904-1906. Nine Pams.
H. F. Palmer, Chicago. Handbook for Architects and Builders, 1905-6. 2 Books, flexible leather.
E. S. Rice, M. W. S. E., Chicago, Engineer office, Santa Fe System. Set of photographs of Eastern-Oklahoma Ry.
Armour Institute of Technology, Chicago. 14th Annual Year-book, 1906-7. Pam.
D. Van Nostrand Co., New York. Elements of Gas Engine Design, by Sanford A. Moss, 1906. Cloth.
National Association of Stationary Engineers, Report of License Committee, 1906. Cloth.

J, H. Warder, Secretary W. S. E., Chicago. Bennett's translation of Morin's Mechanics, 1860. Cloth.

Universal Portland Cement Co., Chicago. The Process of Concreting. (Reprint from Taylor & Thompson's book.) 1906. Cloth.

E. E. R. Tratman, M. W. S. E. Chicago. Resident Editor for Engineering News Publishing Co., 8 Pamphlets, Vols. 1-6. Le Canal de Suez, by Voisin Bey. 1902-6.

C. J. Poetsch, M. W. S. E., City Engineer, Milwaukee. Annual report Milwaukee Board of Public Works for 1905. Pam.

U. S. Commissioner of Patents, Washington. Annual Report of Commissioner of Patents for 1905. Pam.

Lindon W. Bates, M. W. S. E., New York. "The Crisis at Panama" 1906. Pam.

Geo. S. Webster, Chief Engineer, Philadelphia Bureau of Surveys. Annual reports for 1905. Cloth.

EXCHANGES.

Ohio Engineering Society (formerly Ohio Society of Engineers and Surveyors). Report of 27th Annual Meeting, Columbus, Ohio, 1906. Pam.

Amer. Ry. Engineering and Maintenance of Way Association. Bulletins Nos. 77 and 78,—"General Spec. for steel railroad bridges," and "The corrosion of fence wire" respectively. 2 Pam.

Engineering Association of New South Wales, Sydney, Australia. Proceedings, Vols. XII., XIII. and XIV., 1897-99, and XIX. and XX., 1903. 5 Vols. Cloth.

Lawrence, Mass., City of. Annual Report of Water Board to the City Council, 1905. Pam.

Ohio State Geologist. Bulletin No. 8, Salt Deposits and the Salt Industry in Ohio. Pam.

National Association of Cotton Manufacturers. Transactions, 1906. Boards.

Liverpool Engineering Society. Transactions, 1905-6. Pam.

Canadian Society of Civil Engineers, Montreal. Transactions 1905, Vol. XIX., Part I. January-June, 1905.
Transactions 1905, Part 2. Pam.

Institution of Civil Engineers. Minutes of Proceedings, Vol. CLXIV, August, 1906. List of Members, Constitution, etc., 1906.

Institution of Civil Engineers, London. Proceedings, Part 3, 1906. Pam.

National Fire Protection Association, Chicago. Directory, 1906. Pam.

American Railway Master Mechanics Association, Chicago. Proceedings 39th annual convention, 1906. Half leather.

F. G. Ewald, M. W. S. E., Springfield, Ill. Special Report, Illinois Railroad and Warehouse Commission, Revision of Schedule 1902-6. Leather.

American Mining Congress, Denver, Colo. Proceedings, eighth annual session, 1905. Pam.

Institution of Mechanical Engineers, London. Proceedings, Part 2, 1906. Pam.

Western Railway Club, Chicago. Vol. 18, Proc. Sept., 1905-May, 1906. Half leather.

American Electrochemical Society. Vol. 9, Transactions, ninth general meeting, 1906. Cloth.

North of England Institute of Mining and Mechanical Engineers, Annual Reports of the Council and accounts for the years 1905-6. Pam.

Institution of Naval Architects, London. Transactions for 1906. Cloth.

Institution of Electrical Engineers. London. Proceedings, Vol. 37, issued September, 1906; also index and List of Members, 1906. 2 Pams.

National Fire Protection Association. Quarterly Bulletin, October, 1906.
Western Australia Geological Survey. Bulletins No. 21 and 22, with maps, 2 Pams.
North-east Coast Institution of Engineers and Shipbuilders. Transactions 22nd session, 1905-6. Half-leather.
Western Australia Chamber of Mines. Monthly Journal, Vol. 5, Nos. 1-7 inclusive. 7 Pams.
Engineers' Society of Western Pennsylvania, Pittsburg. Index of Proceedings. Vol 1-20 inclusive. Pam.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey, Department of Interior. 24 Pams.
- Production of tin in 1905. Hess.
- Production of asphaltum and bituminous rock in 1905. Hovey.
- Production of steel-hardening metals in 1905.
- Production of iron ores in 1905. Bickinbine.
- Production of maganese ores in 1905. Bickinbine.
- Production of barytes in 1905. Eckel.
- Production of mineral paints in 1905.
- Production of sulphur and pyrite in 1905.
- Production of bismuth in 1905.
- Production of graphite in 1905.
- Production of zinc and lead ores in 1905.
- Production of antimony in 1905.
- Production of sand and gravel in 1905. Coons.
- Production of natural gas in 1905. Griswold.
- Production of platinum in 1905. F. W. Horton.
- Production of petroleum in 1905. W. T. Griswold.
- Production of borax in 1905.
- Production of bauxite and aluminum in 1905.
- Production of lead in 1905. Kirchhoff.
- Production of copper in 1905. Kirchhoff.
- The manufacture of coke in 1905. Parker.
- Statistics of the Clay Working Industries in the United States, 1905.
- The Stone Industry in 1905. Eckel.
- Contributions to Economical Geology, 1905. Bulletin No. 285.

U. S. Department of Commerce and Labor. Bureau of the Census, 3 Pam.
- Bulletin No. 48, Census of Manufactures, 1905, La., Miss. & Tex.
- Bulletin No. 49, Census of Manufactures, 1905, Cal., Oregon, Wash.
- Bulletin No. 50, Statistics of Cities with population over 30,000. 1904.
- Special Census Reports, "The Blind and Deaf, 1900." Cloth.
  - "Paupers and Almshouses, 1904." Cloth.
  - "The Insane and Feeble-Minded, 1904." Cloth.
- Bulletins 52-57 incl. 6 Pam.

U. S. Department of Agriculture, Practical information for beginners in irrigation. Fortier. Pamphlet.
U. S. Department of Interior, Reclamation Service, various specifications, with drawings. Pam.
U. S. Geological Survey, Department of Interior, 18 Pam.
- The Cement Industry in the United States in 1905.
- Water Supply and Irrigation Papers, Bulletins 155, 156, 158, 163, 170, 173, 176, 178.
- Geological Bulletins Nos. 275, 277, 278, 280, 281, 282, 288, 290.
- Professional Paper No. 50.

U. S. Department of Agriculture. Yearbook for 1905. Cloth.
U. S. Department of Agriculture, Experiment Station; The State Engineer and his relation to irrigation. Teele. Pam.
U. S. Department of Agriculture, Forest Service, 15 Pam.
Bulletins Nos. 69 and 73; circulars Nos. 39, 40, 41.
Progress of Forestry in 1905.
Prolonging the life of telephone poles, 1905.
How to grow young trees for forest planting, 1905.
Waste in logging southern yellow pine, 1905.
Circulars Nos. 38, 42, 43, 44, 50 and 51.
U. S. Department of Interior, Commissioner of Education. Report Commissioner of Education for year 1904. Cloth.

TRADE CATALOGUES.

James B. Clow & Sons, 4 by 6 pam. Handbook for Steam and Hot Water Heating Contractors.
B. F. Sturtevant Company, Boston, Mass., Catalogue No. 135, Sturtevant Blowers, etc. Pam.
Allis-Chalmers Co., Milwaukee, Wis. Bulletin No. 1054. Steam Turbines and Generators. Pam.
General Electric Co., Schenectady, N. Y. Catalogue of Specialties, June and August, 1906. Cloth.
Frank H. Pond, Chicago Manager, American Stoker Co., two catalogues of stokers. Pam.
United States Steel Sheet Piling Co., Chicago, Catalogue of Steel Sheet Piling, 1906. Pam.
Joseph Dixon Crucible Co., Jersey City, N. J. "Through Frisco's Furnace." Pam.
Chicago Pneumatic Tool Co., Chicago, Catalogue No. 20, Franklin Air Compressors. Pam.
Century Electric Co., St. Louis, Mo. Bulletin No. 7. Single Phase Alternating Current Motors. Pam.
General Electric Co., Schenectady, N. Y.. Catalogue No. 7601, of Railway Supplies, 1906. Cloth.
Benjamin Electric Mfg. Co., Chicago, Catalogue of Wireless Clusters and Lighting Specialties. B-17. Pam.
Acme Road Machinery Co., Frankfort, N. Y., Catalogue No. 4, Road Building Machinery, etc. Pam.
Climax Road Machine Co., Marathon, N. Y., Catalogue of Crushing and Road Machinery. Pam.
A. B. Porter, M. W. S. E., Chicago, Catalogue of Technical Thermometry, Cambridge Scientific Instrument Co., England. 1906.
Niles-Bement-Pond Co., New York, Catalogue of Machine Tools, 1903. Cloth.
Julian Scholl & Co., New York, Catalogue of Reliance Stone Crushing Machinery. Pam.
Chester B. Albree Iron Works, Allegheny, Pa., Catalogue No. 6 of Pittsburg Riveting Machines. Pam.

---

MEMBERSHIP.

*Additions to Membership*:
Avery, Frederick H., 101 Howard Ave., Austin, Chicago............Active
Balsley, Eugene A., 40th and Stewart Ave., Chicago, transferred from
..............................................Junior to Active
Burgess, Fred H., Lenox, Tenn....................................Junior
Cromwell, Harry D., Woodward, Okla..............................Junior
Dalstrom, Oscar F., 1430 Eastwood Ave., Chicago, transferred from
..............................................Associate to Active
Durham, Robert P., 623 The Temple, Chicago......................Active

Fridstein, Hymen, 444 S. Hermitage Avenue, Chicago................Active
Fulcher, James E., 1215 Volland St., Ann Arbor, Mich................Active
Gould, Lawrence E., 1660 Monadnock Block, Chicago................Active
Hardenbergh, R. W., 740 The Rookery Chicago........................Active
Harris, William H., 219 Humphrey Ave., Oak Park, Ill................Active
Hiller, Eugene F., 3844 Lake Ave., Chicago..........................Junior
Hotchkiss, W. O., Madison, Wis......................................Active
Jacobi, W. O., 730 Monroe St., Chicago..............................Junior
Jefferies, Frederick L., Sears, Roebuck & Co., Chicago...............Active
Kuss, Robert H., 228 S. Clark St., Chicago..........................Active
Lawry, Raymond G., 4145 Indiana Ave., Chicago.......................Active
Morgan, Elias R., 749 Railway Exchange Bldg., Chicago...............Junior
Morse, Henry M., 2292 N. Ashland Ave., Chicago......................Active
Moskovitz, Jerome A., Belen, N. Mex.................................Junior
Ott, Harry J., 1210, 315 Dearborn St., Chicago......................Junior
Pierce, Joseph N., 6507 Rhoades Ave., Chicago.......................Associate
Reynolds, Myron B., 1512 Eastwood Ave., Chicago.....................Junior
Robinson, Wm. C., 5222 Jefferson Ave., Chicago......................Active
Sanderson, John C., 1204 Sherman St., Evanston, Il..................Active
Saxe, Alfred J., 815 Railway Exchange Bldg., Chicago................Active
Sayers, A. J., Care Link Belt Mach. Co., Chicago....................Active
Sherman, Carlton F., Asst. Engr. I. C. R. R., McComb, Miss transferred from ........................................Junior to Active
Smith, Chas A., Asst. Engr., C. & W. I. R. R., Dearborn Sta., Chicago ..............................................................Active
Spurling, O. C., 1676 W. Congress St., Chicago......................Active
White, James M., Engineering Hall, U. of I., Urbana, Ill............Active
Youtsey, Floyd S., 229 McClure Ave., Elgin, Ill.....................Active

*Deceased*:

Abbott, Arthur Vaughan, New York City.
Green, O. B., Chicago.

*Corrected Addresses*:

Allen, P. C., Div. Supt. G. N. Ry., Great Falls, Mont.
Amari, Chas. A., 5702 S. Ashand Ave., Chicago.
Armstrong, W. C., Terminal Engineer, C. & N. W. Ry. Co., 215 Jackson Blvd., Chicago.
Barker, Perry, Care Boiler Division, Coal Testing Plant, St. Louis, Mo.
Bayliss, John Y., Leslie, Searcy Co., Ark.
Berkeley, R. C., 628 Montgomery St., San Francisco, Cal.
Binkley, Geo. H., 6744 Perry Ave., Chicago.
Brown, J. H., Care Western Pacific Ry., Const. Dept., Long Valley P. O. Cal.
Brown, M. L., Zeigler, Ill.
Carlton, W. G., Pt. Morris Power Sta., 142nd St. and E. River, New York, N. Y.
Caruthers, Wm. S., Clairville, Cal.
Cole, George, Res. Engr., C., M. & St. P. Ry. Co., Forsythe, Mont.
Cummins, Thos. R., Care J. G. White & Co., Pottsville, Pa.
Drury, Frank H., 1314 New Fisher Bldg., Chicago.
Ely, Howard M., 346 W. Washington Ave., Madison, Wis.
Gaffin, W. W., Care C. & N. W. Ry. Co., North Fond du Lac. Wis.
Grady, John E., Great Lakes Dredge & Dock Co., Cleveland, O.
Gray, Elam, 293 High St., Blue Island, Ill.
Gray, J. C., Asst. Engr. Oregon Short Line R. R. Co., Salt Lake City, Utah.
Haussman, H. Jr., 1036 Hood Ave., Edgewater, Ill.
Hegardt, G. B., Chamber of Commerce, Portland, Oregon.
Holcomb, C. S., Box No. 407, Hinsdale, Ill.
Howard, F. H. P., 4650 Woodlawn Ave., Chicago.
Hoyt, W. A., 438 Belden Ave., Chicago.

Hunt, L. A., Hunt Engineering Co., Iola, Kans.
Hurd, C. H., Indianapolis Water Co., Indianapolis, Ind.
Jackson, Geo. W., Borland Bldg., Chicago.
Johnson, Maro, 6110 Mornoe Ave., Chicago.
Joor, Sam'l, 1016 New Fisher Bldg., Chicago.
Love, Wm. S. M. E., Care Wheeler Condenser & Engineering Co., 42 Broadway, New York, N. Y.
Macdonald, F. A., 1613 Iowa St., Davenport, Iowa.
Maddock, Geo. F., Care H. M. Byllesby & Co., 500 American Trust Bldg., Chicago.
Marston, W. S., 288 Jewett Ave., W. New Brighton, L. I., N. Y.
Merriam, L. B., Div. Engr., Grand Trunk Pacific R. R., Winnipeg, Man.
Murray, Edward, Care C., M. & St. P. Ry. Co., Miles City, Mont.
North, A. T., R. 811, 135 Adams St., Chicago.
O'Byrne Frank J. J., R. 20, 90 La Salle St., Chicago.
Parker, W. A., Care The Drexel Hotel, Omaha, Neb.
Parsons, Walter J., 213 Elm St., Swissvale Sta., Pittsburg, Pa.
Perkins, F. W., Consulting Engineer, International Salt Co., Chicago.
Plessner, Otto, 1639 Monadnock Block, Chicago.
Reef, A. J., Care H. C. Frick Coke Co., Scottdale, Pa.
Rosing, Anton S., 26th St. & Commercial Ave., Chicago Heights, Ill.
Rossiter, J. A., 347 Lawrence Ave., Ravenswood Chicago.
Snyder, C. H., Care Milliken Bros., 509 Eddy St., San Francisco, Cal.
Soper, Ellis C., South Pittsburg Tenn.
Stevens, H. E., Care Chief Engr's Office, U. P. Ry. Co., St. Paul, Minn.
Stone, A. H., 200 W. Monroe St., Springfield Ill.
Swanitz H. W., Care Bank of Tamaroa, Tamaroa, Ill.
Thomas, M. E., Shawano, Wis.
Torrance, W. M., 63 Sanford St., E. Orange, N. J.
Townsend Chas. McD., 813 Prospect Ave., S. E., Cleveland, Ohio.
Troxel, I. W., 314 Masonic Temple, Elyria Ohio.
Wahl Henry R., Elvins, Mo.
Wentz, Robert F., Fleetwood, Pa.
Wiener, C. A., 426 E. Superior St., Flat F., Chicago.
Wood, C. M., Care Mech. Engr's Office, U. P. R. R. Co., Omaha, Neb.
Wood, E. N., 79 Market St., Chicago.
Wright, Joseph, Engineer U. S. R. S., Corbett, Wyo.